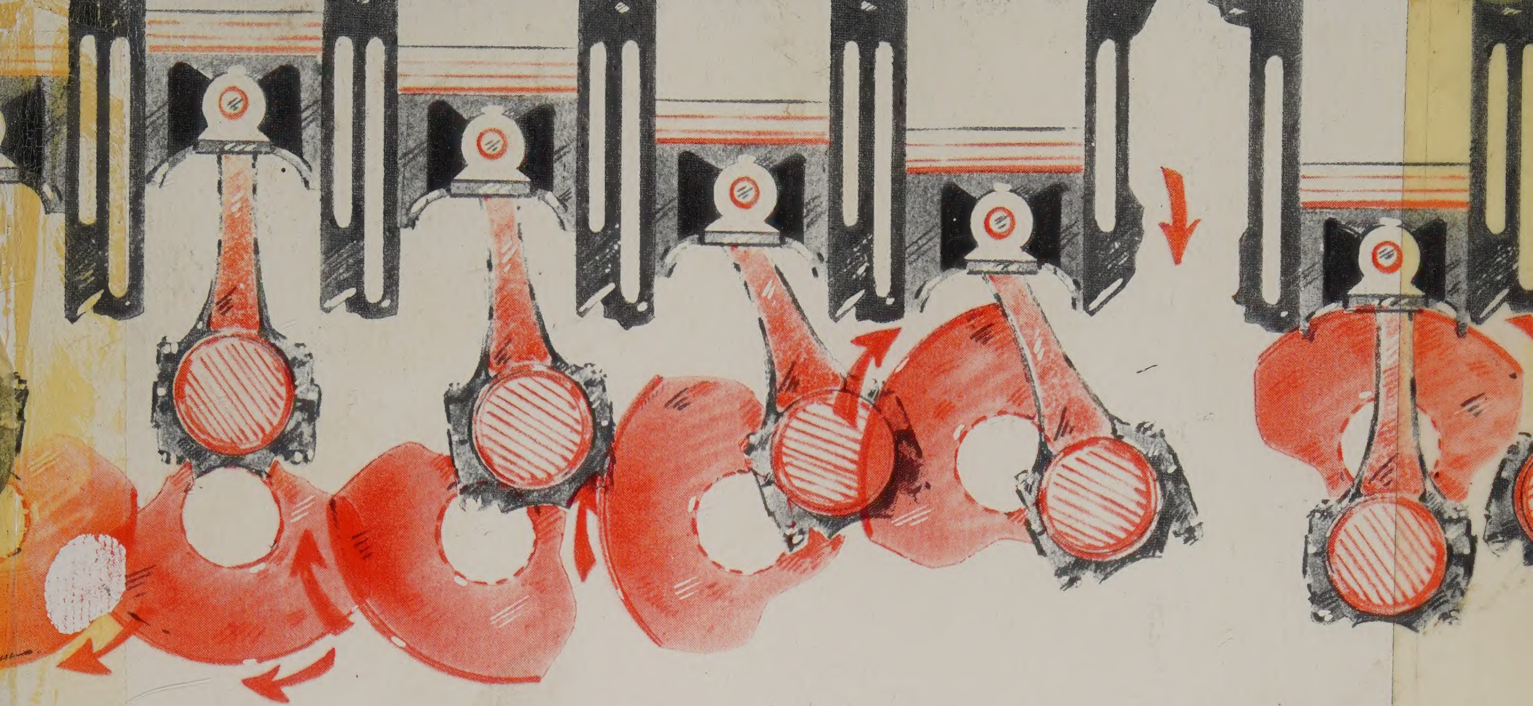
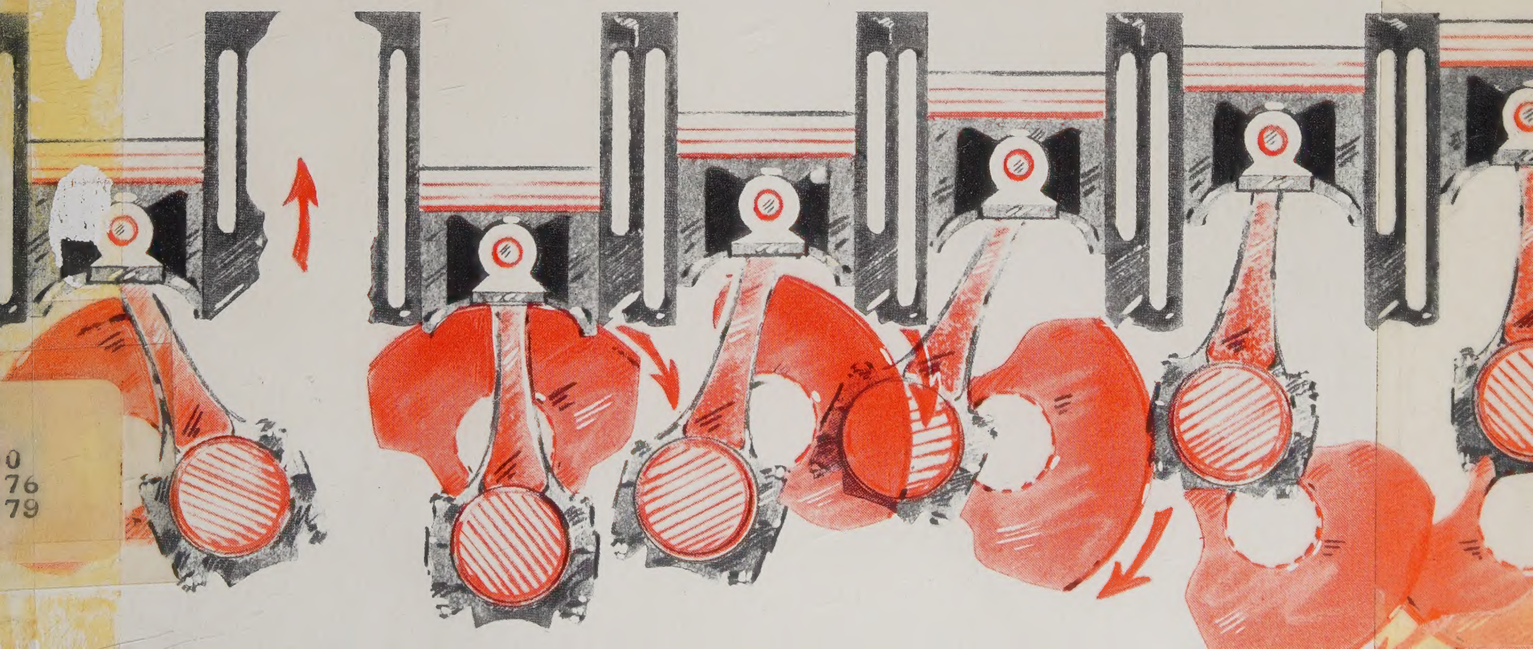


2nd Edition

SMALL ENGINE MECHANICS

William H. Crouse

Donald L. Anglin



SMALL ENGINE MECHANICS
Second Edition

William H. Crouse
Donald L. Anglin

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Mr. Crouse has contributed numerous articles to automotive and engineering magazines and has written many books about science and technology.

William H. Crouse's outstanding work in the automotive field has earned for him membership in the Society of Automotive Engineers and the American Society of Engineering Education.

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Special thanks are due to the following organizations for information and illustrations they supplied: AC Spark Plug Division of General Motors Corporation; Ariens Company; Black and Decker Manufacturing Company; Briggs & Stratton Corporation; Buick Motor Division of General Motors Corporation; Champion Spark Plug Company; Chevrolet Motor Division of General Motors Corporation; Clinton Engines Corporation; Cushman Motors Division of Outboard Marine Corporation; Dana Corporation; Delco-Remy Division of General Motors Corporation; Evinrude Motors Division of Outboard Marine Corporation; Federal-Mogul Corporation; Ford Motor Company; General Motors Corporation; Gould, Incorporated; Harley-Davidson Motor Company, Incorporated; Homelite Division of Textron, Incorporated; Honda Motor Company, Limited; Husqvarna; Imperial Brass Manufacturing Company; International Harvester Company; Jacobsen Manufacturing Company; The J. I. Case Company; Johnson Motors Division of Outboard Marine Corporation; Kohler Company; Lawn Boy Division of Outboard Marine Corporation; The L. S. Starrett Company; Mercury Marine Division of Brunswick Corporation; Onan Corporation; Outboard Marine Corporation; Petersen Manufacturing Company, Incorporated; Selastomer Division of Microdot, Incorporated; Service Parts Division of Dana Corporation; Snap-on Tools Corporation; Suzuki Motor Company, Limited; Tecumseh Products Company; Teledyne Wisconsin Motor; 3M Company; Toyo Kogyo Company, Limited; TRW, Incorporated; Union Carbide Corporation; United Delco Division of General Motors Corporation; Volkswagen of America, Incorporated; Waldes Kohinoor, Incorporated; Yamaha Motor Company, Limited; and Yanmar Diesel Engine Company, Limited.

To all these organizations and the people who represent them, sincere thanks.

William H. Crouse
Donald L. Anglin

Preface

The widespread acceptance of *Small Engines: Operation and Maintenance* has encouraged the publication of this second, greatly enlarged edition. In this revision, many changes have been made and much new material has been included. Retitled *Small-Engine Mechanics,* this edition reflects the significant technological advancements that have been made in small engines. Engines have been improved year after year to make them more economical, more powerful, more flexible, and longer lasting. Now, engine-design work is aimed toward reduction of atmospheric pollution and noise, resulting in the introduction of various engine emission controls as well as intensifying the search for alternative power plants and the modification of the present piston engine.

Many of the changes and additions to the book resulted from suggestions made by its users. These cover new material on safety in the shop, fuels and combustion, emission controls, overhead camshaft engines, brushless alternators with solid-state regulators, electronic and capacitor-discharge ignition systems, and many other new developments.

Another important feature of the second edition is that metric equivalents of all United States Customary measurements have been added following each USC measurement. When a United States Customary measurement is given, it is usually followed by its metric equivalent in brackets; for example, 0.002 inch [0.051 mm].

The book is larger. The bigger $8^1/_2 \times 11$ [216×279 mm] format permits larger illustrations for easier understanding of details. The text has been almost totally rewritten to simplify explanations, shorten sentences, and improve readability.

Correlated with the textbook is an all new *Workbook for Small-Engine Mechanics*. It includes the basic engine-service jobs as proposed by small-engine instructors and the small-engine manufacturers. Taken together, *Small-Engine Mechanics* and the workbook provide the user with the background information and "hands-on" experience needed to become a qualified small-engine mechanic.

To assist the instructor, the *Instructor's Planning Guide for Small-Engine Mechanics* is available. This instructor's guide was prepared to help the instructor do the best possible job of teaching by most effectively using the textbook, workbook, and other related instructional materials. The instructor's guide also includes the answer key for the tests at the end of each jobsheet in the workbook.

With the textbook, the workbook and instructor's guide make up an instructional program that will fit any teaching situation. The program is flexible enough to fit classroom instruction needs, shop activities, individual instruction, and "do-it-yourself" courses for hobbyists and consumers.

The authors are grateful to the many people, both in industry and in education, whose contributions and comments helped shape this book. They share, with the authors, a hope that this program will help achieve the aims of all who work in the field of small-engine mechanics instruction: to train high-caliber small-engine mechanics who are capable of taking their proper place in the small-engine servicing profession.

William H. Crouse
Donald L. Anglin

To The Student

This book, *Small-Engine Mechanics,* was prepared with you, the student, in mind. It covers all aspects of small-engine construction, operation, applications, maintenance, and servicing. When you have finished this book and the related shopwork, you should be ready to enter the world of small-engine servicing.

Here are some hints on how to get the most out of the book. If you follow these suggestions, you will find studying much easier.

1. The first thing to do before studying the assignment is to turn the pages one by one. Look at the pictures and study the numbered headings. This will give you an idea of what the assignment is about.
2. If you are starting a new chapter in the textbook, read the Student Performance Objectives listed at the beginning of each chapter. These objectives tell you what you will learn from the chapter.
3. Read the first section in the assignment. Then read the section again, slowly and carefully, so that you are sure you understand it.
4. Continue studying the pages assigned to you. Read each section carefully. When you come to the Review Questions at the end of the chapter, try to answer the questions. If you can answer them, it means you are doing a good job of studying. If a question stumps you, go back and reread until you have the right answer.
5. If you come to a sentence you don't understand, read it aloud. If this does not help, write it down. Ask your instructor to explain it to you.
6. Don't hesitate to admit that something puzzles you. Everybody gets stuck once in a while.
7. Don't worry about not understanding everything the first time you read it.
8. If you get sleepy, or if your attention wanders—wake up! Stretch. Put cold water on your face. Have coffee or a soft drink. Then get back to work!

GETTING PRACTICAL EXPERIENCE

This book alone will not make you an expert in small engines. You also need practice in handling engine parts and the tools of the trade. If you are taking a regular course in small-engine servicing, you will get this practice under the supervision of a teacher. If you are not taking a regular course, you can still get practical experience in a local shop where small engines are serviced. If you are already working in a repair shop, this book will broaden your knowledge of small engines.

SERVICE PUBLICATIONS

While you are in the shop, study the various service publications. All small-engine manufacturers publish service manuals on their engines. Studying these manuals will provide you with specifications and special procedures.

KEEPING A NOTEBOOK

Keeping a notebook is a valuable part of your training. Start it now, at the beginning of your studies. Your notebook will help you in many ways: it will be a record of your progress, it will become a ready reference source, it will help you learn, and it will help you organize your training program so that it will do you the most good.

When you study a chapter in the book, have your notebook open in front of you. Start with a fresh notebook page at the beginning of each lesson. Write the textbook page number and date at the top of the page. As you read your lesson, jot down important points.

In the shop, use a small scratch pad or cards to jot down important points. You can transfer these notes to your notebook later.

Use your notebook to make sketches of wiring or hose diagrams, fuel circuits, and so on. File articles and illustrations from technical and trade magazines in your notebook. Also, save instruction sheets that come with service parts.

Your notebook will become a valued possession—a continuing record of what you have learned and are learning about small-engine mechanics.

GLOSSARY AND INDEX

A glossary (a definition list) of small-engine terms is given in the back of the book. Whenever you have any doubt about the meaning of a term or what purpose some part has, refer to this list. Also, there is an index at the back of the book. This index will steer you to the page in the book where you will find the information you are seeking.

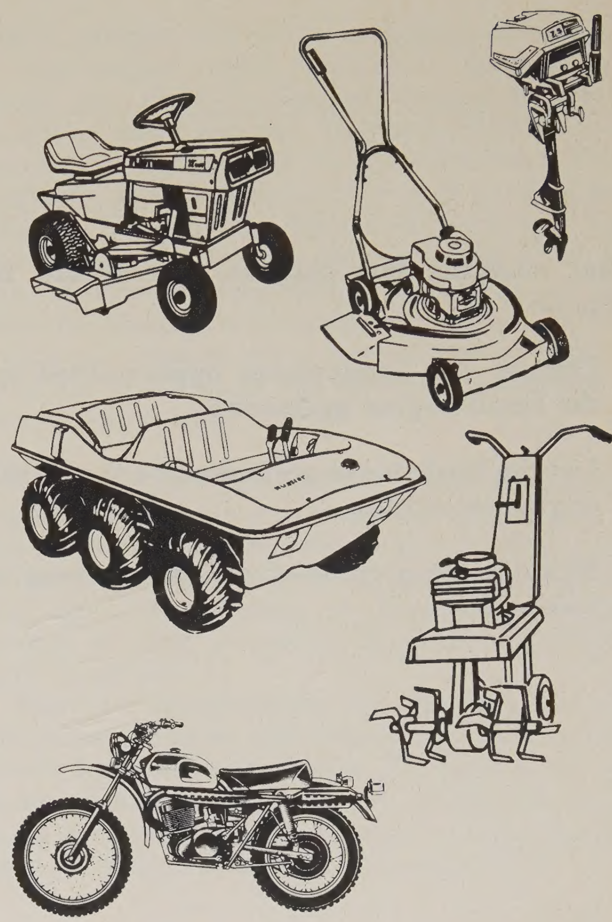
And now, good luck to you. You are studying a fascinating and admirable machine—the small engine. Your studies can lead you to success in the small-engine field, a field where opportunities are nearly unlimited.

William H. Crouse
Donald L. Anglin

one

SHOPWORK AND SHOP TOOLS

This is your introduction to the small engine and the small-engine service industry. In this first part we point out many opportunities for jobs in the small-engine service field. We describe shopwork and shop manuals that you will use. We discuss safety in the shop, the basics of shopwork, fasteners, and tools. There are seven chapters in Part One of *Small-Engine Mechanics:*



Chapter 1

Opportunities for the Small-Engine Technician

After studying this chapter, you should be able to:

1. **Discuss the employment opportunities for the small-engine technician**
2. **List the basic tasks performed by the small-engine technician**
3. **Describe the purpose of, and how to keep, a notebook**

○ 1-1 NUMBER OF SMALL ENGINES IN USE The variety of jobs that small engines do is amazing (Fig. 1-1). Small engines are used in lawn mowers, edgers, minibikes, snowblowers, chain saws, water pumps, air compressors, sprayers, grinders, post-hole diggers, and other vehicles and equipment. It is estimated that there are more than 100 million small engines now in use in the United States. At least 10 million more engines come off the assembly line each year.

○ 1-2 NEED FOR SERVICE Several million small engines are junked each year. Some of these engines really wear out. Many could have given additional service if they had been serviced and repaired. Many could have lasted much longer if the owners had not abused them and had given them proper care and service. This is what this book is all about—how to take care of small engines properly so they will give the user the life that is built into them.

Small engines are like any other machine. They will give good service if properly cared for. But they will wear rapidly and fail if they are not cared for properly. That is where you, as a small-engine technician, come in. You will service and repair small engines so they will last longer, operate better, and give better performance.

○ 1-3 TYPES OF OPPORTUNITIES Many small-engine technicians start out in a small way on a part-time basis. As they learn about small engines, they get started making money by servicing the engines of neighbors and friends (Fig. 1-2). If they do a good job, this part-time work can grow into a full-time business. But there are certain cautions you must heed if you do small-engine work in your home or garage. First of all, gasoline is dangerously explosive. Gasoline vapor in a basement can blow a house right off its foundations. And the explosion can injure or kill anyone in that basement. Also, running an

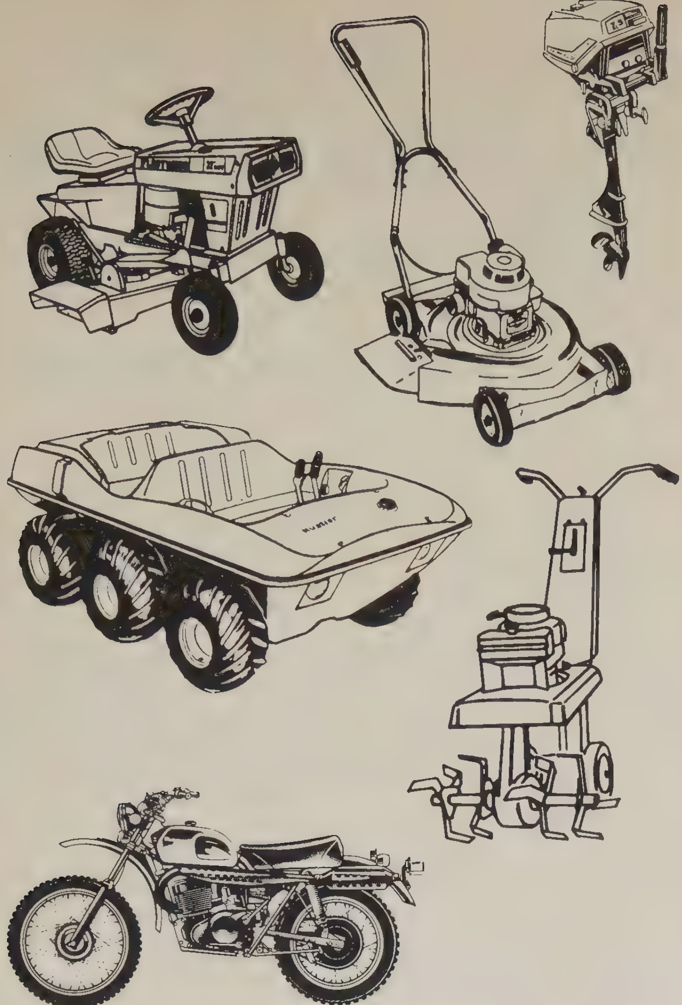


FIG. 1-1 Some of the many types of small-engine-powered vehicles and equipment that have become part of our way of life.

engine in a closed room or space can kill you. A running engine puts out deadly carbon monoxide.

We will have more to say about these dangers in Chap. 3, which concerns safety in the shop. Meantime, there is another problem of a different sort that might come up if you do work in your home or garage. This is that you must observe local residential zoning laws. In many communities, there are ordinances or laws that prohibit certain kinds of business in residential areas. You would have to check out the local regulations with city hall before you began to set up a regular business of servicing small engines in your home.

If you start a business of your own and if you need replacement parts for a small engine, you can usually get them through one of the authorized dealers in your neighborhood. Look in the phone book.

Many small-engine technicians, after they finish their small-engine courses, go to work in an established service shop. Some shops are set up especially to service small engines. Regular automotive repair

FIG. 1-2 Many small-engine service technicians start out by earning money servicing the powered equipment of neighbors and friends.

shops, garages, and service stations sometimes have a small-engine repair department. Some of these shops are factory-authorized dealers for certain makes of small engines. They specialize in one or more lines—for example, Briggs & Stratton or Kohler engines—and stock the small-engine parts for these engines. Normally, the dealers will service all kinds of small engines, not just the engines for which they are authorized dealers. Another possible source of job opportunities is in motorcycle repair shops. Although motorcycle engines are a special type of small engine, the basic repair and servicing procedures are similar for all small engines.

○ 1-4 YOUR OWN BUSINESS There are many advantages in running your own business (Fig. 1-3). You are on your own and you cannot be fired from the job. Whatever income you receive is yours (after expenses and taxes). You become an independent business person. As such, you are an important individual in your hometown.

There are disadvantages, too. You may find yourself working harder and longer hours than you ever would work for someone else. You have to put your business sense to work, as well as your hands. You have to keep records and, if you hire others, you must take on responsibilities for these employees.

FIG. 1-3 Your part-time business of servicing small engines can grow until it becomes your full-time business.

○ 1-5 YOUR JOB AS A SMALL-ENGINE MECHANIC Regardless of where you work in the business, the basic tasks are the same. As a small-engine mechanic, you must fix the small gasoline engines that are used to power lawn mowers, garden tractors, and similar machines. You will have to know how to use hand tools and measuring tools, locate troubles, disassemble engines, examine parts for defects, and repair or replace these parts. Installing piston rings and bearings also is part of the job. Then when the engine is all together, you must clean and adjust the carburetor and magneto, service the starter, and troubleshoot and diagnose and repair any other problems. Afterwards, you must test the engine for proper performance and install the engine in the machine it powers.

When you consider all the things that a small-engine mechanic must know how to do, there doesn't seem to be anything small about the job. It is just as challenging and as rewarding as working on larger engines. And it is for this work that the course you are taking and this textbook, *Small-Engine Mechanics,* aim to prepare you. Their purpose is to provide you with the knowledge and skills that you need to be a professional small-engine mechanic.

○ 1-6 KEEPING A NOTEBOOK Keeping a notebook is a valuable part of your training to become an expert small-engine mechanic. Start it now, at the beginning of your study of this textbook. Your notebook will help you in many ways. It will be a record of your progress in your studies. It will become a storehouse of valuable information you will refer to time after time. It will help you learn. And it will help you organize your training program to do you the most good. Do not overlook this valuable way of becoming the small-engine expert you want to be. Keep a notebook!

REVIEW QUESTIONS

At the end of each chapter in this book is a series of review questions. These questions will help you to review what you have just studied. Try to answer them all. If you are not sure about the answer to any question, reread the section in the chapter that gives you the answer.

1. How many small engines are in use in the United States?
2. How many new small engines are sold each year in the United States?
3. Why do small engines wear out?
4. What opportunities are there for qualified, trained small-engine mechanics?
5. What things must you check before doing much small-engine work at home?
6. What advantage is there to owning your own business?
7. How can keeping a notebook help you learn small-engine mechanics?

SELF PROJECT

Self Projects are projects you do yourself, on your own. Their purpose is to help you understand more about the small-engine service business. They will help you learn about the many kinds of jobs there are in this business.

Look in the Yellow Pages of your local telephone directory under "Engines—Gasoline." Make a list of the various businesses listed. You may be surprised at the number and variety of firms in the small-engine business.

Chapter 2

Shopwork and Shop Manuals

After studying this chapter, you should be able to:

1. **List the six steps in any service job and explain what each means**
2. **Discuss the various sources of small-engine service information and specifications**
3. **Explain the purpose of the illustrations in this textbook and describe the types used**

○ 2-1 STEPS IN SERVICE JOBS Service on small engines and on equipment using small engines can be classified into six basic steps:

1. Measuring
2. Disassembly
3. Machining
4. Installing new parts
5. Reassembly
6. Making adjustments

Many jobs require fewer steps. Let us look briefly at each step.

○ 2-2 MEASURING Many times, before you begin work on an engine, you have to find out what is wrong with it. You often begin by measuring. This does not necessarily mean you get out your tape measure. When you listen to a noisy engine, you are measuring the sounds of the faulty engine against the sounds of a good engine as you remember them.

Whenever you service and repair an engine, you will be taking various measurements. For example, you may measure point opening in the magneto, the valve-stem clearance, engine-cylinder diameter, and so on. You may be taking these measurements in the United States Customary System (inches and fractions of inches) or in the metric system (centimeters and millimeters). We describe these two systems along with measuring instruments in Chap. 7.

○ 2-3 DISASSEMBLY To repair an engine or to perform a service such as installing new piston rings, you have to disassemble ("tear down," or take apart) the engine. We describe in detail, in later chapters, how to disassemble engines.

○ 2-4 MACHINING When you disassemble an engine, you may find that some parts are so worn they must be thrown away. Other parts may require nothing more than machining. For example, the valves in a four-cycle engine may require grinding. Power tools are required for most machining jobs. We explain in a later chapter how to grind valves and the machine used to do this job.

○ 2-5 INSTALLING NEW PARTS If the old parts are worn so much they cannot be used, then new parts are required. New engine parts can be purchased from a local small-engine parts dealer. If the dealer does not have a part in stock, the dealer then orders it from a regional warehouse.

○ 2-6 REASSEMBLY After the parts have been machined or replaced with new parts, everything is put back together. This is called reassembly, or *buildup*.

○ 2-7 ADJUSTMENTS As any machine runs, parts tend to wear. After some time has passed, the wear is great enough so that adjustment is needed. For example, if magneto points or valves wear, adjustments have to be made to restore the proper specifications.

○ 2-8 SPECIFICATIONS In the shop you will often hear the word "specifications" or "specs." The specs are the right measurements for the engine you are working on. These measurements, or specs, tell you what the cylinder diameter should be, for example. They are set by the factory and are included in the manufacturer's shop manual. The specs also give you the allowable wear. If the cylinder wears beyond this allowable dimension, service is required. Valves, magneto points, and other adjustable parts must be adjusted to specs whenever the engine is serviced.

○ 2-9 SHOP MANUALS Every engine manufacturer issues a shop manual such as shown in Fig. 2-1. These manuals cover all service procedures, including the specs, on the engines manufactured by the company. When you need specific information on an engine, you look it up in the manual covering that engine (Fig. 2-2).

Manuals for specific engines can be purchased from the manufacturer. You should have the service manual that applies before you work on an engine. You will find, however, that the general servicing procedures are quite similar for all engines. The differences lie in some specific servicing recommendations and in the specifications. If you do not have a manual for an engine you are working on, the authorized dealer for the engine either has the manual for sale or will special-order it for you.

○ 2-10 TYPES OF ILLUSTRATIONS Before we leave the subject of small-engine shop manuals, we would like to explain the various kinds of pictures, or illustrations, you will find in these shop manuals.

Many of the illustrations used in the book have been supplied by the manufacturers of small engines. Therefore, you may be sure that the illustrations are accurate. Also, many of the illustrations have been prepared especially for this book to make it easier for you to understand the text.

Illustrations are of several types, such as external views, sectional views, cutaways, line drawings, and phantom views. For example, Fig. 2-3 is an external view of an engine. Figure 2-4 is a sectional view of an engine. This view is called a sectional view because

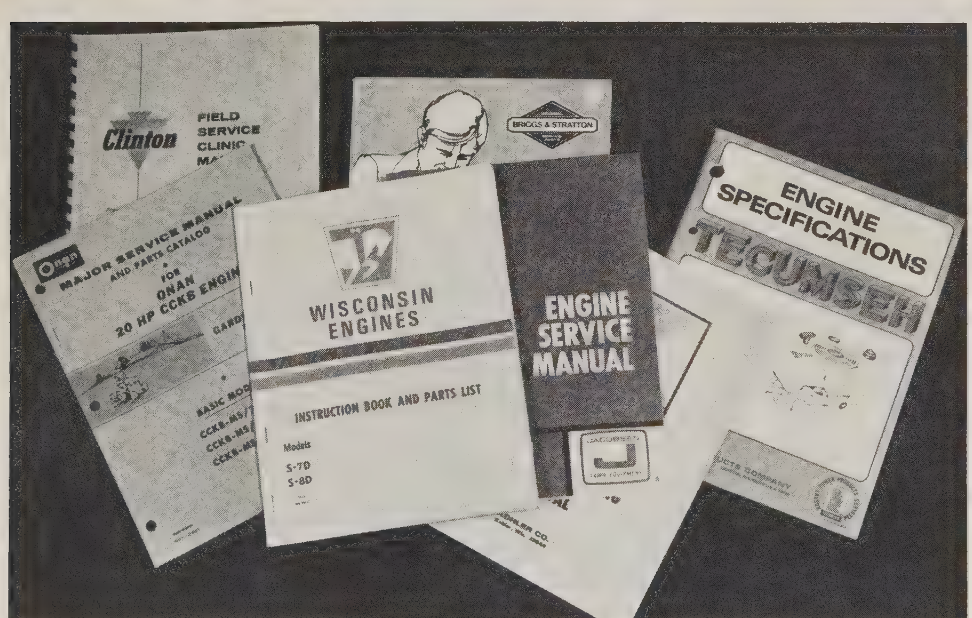


FIG. 2-1 Shop manuals available from the engine manufacturers provide the specs and service procedures.

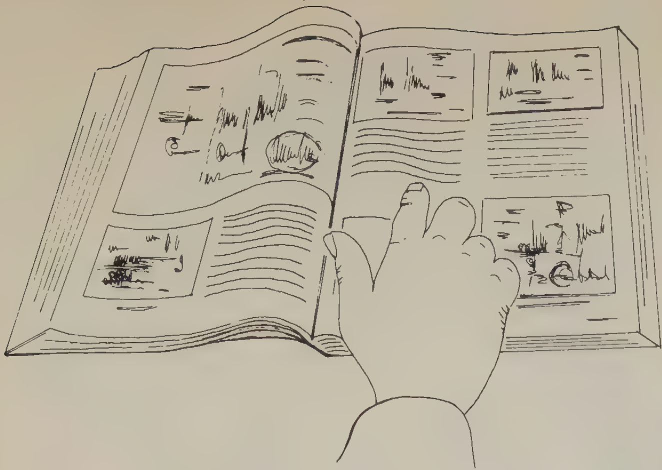


FIG. 2-2 When you need some specific information on a small engine, you look it up in the manufacturer's service manual.

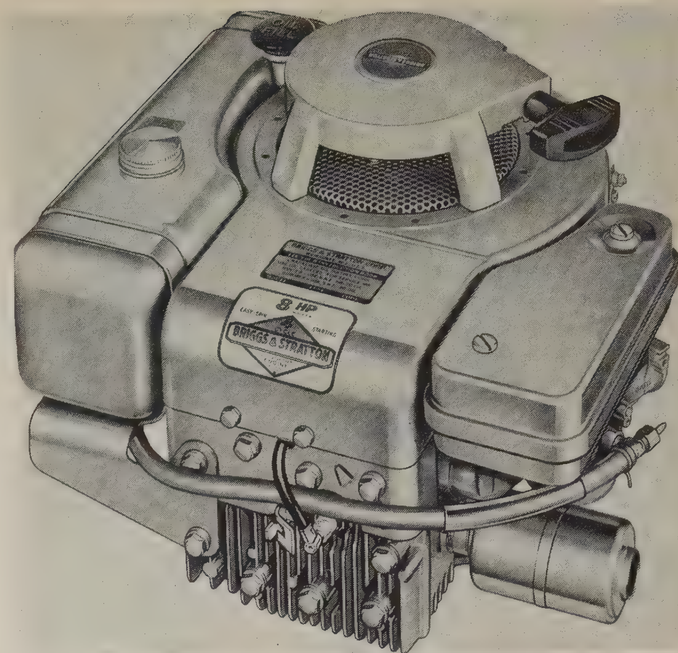


FIG. 2-3 An external view of an engine. *(Briggs & Stratton Corporation)*

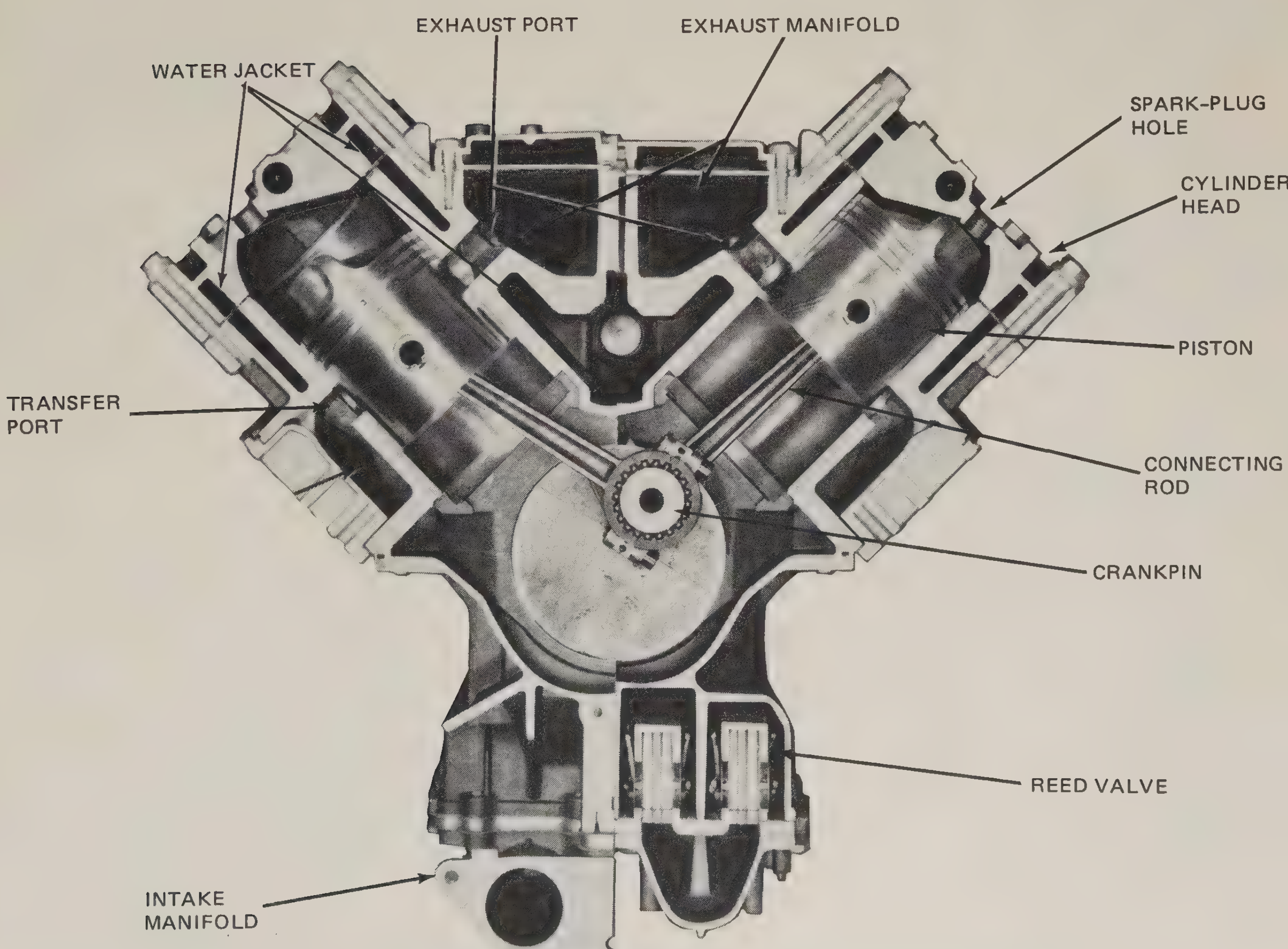


FIG. 2-4 Sectional view from the top of a V-4 two-cycle outboard engine.

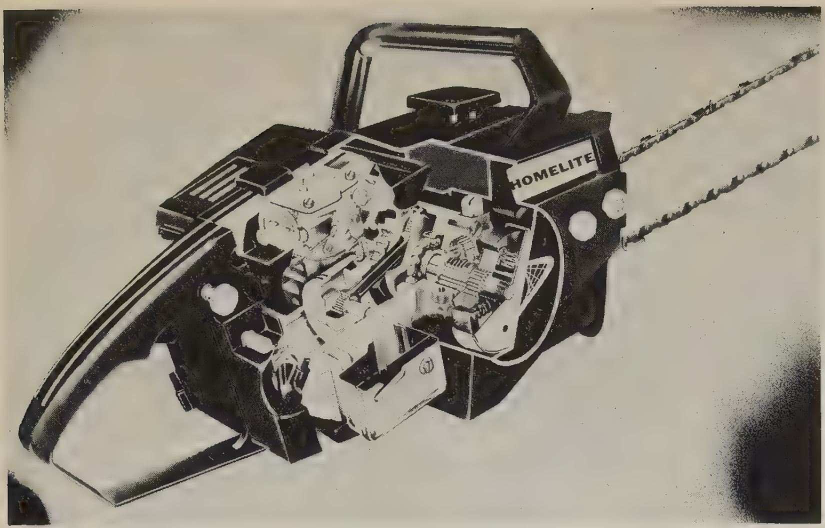


FIG. 2-5 Cutaway view of a chain saw showing the internal construction of the engine. *(Homelite Division of Textron, Inc.)*

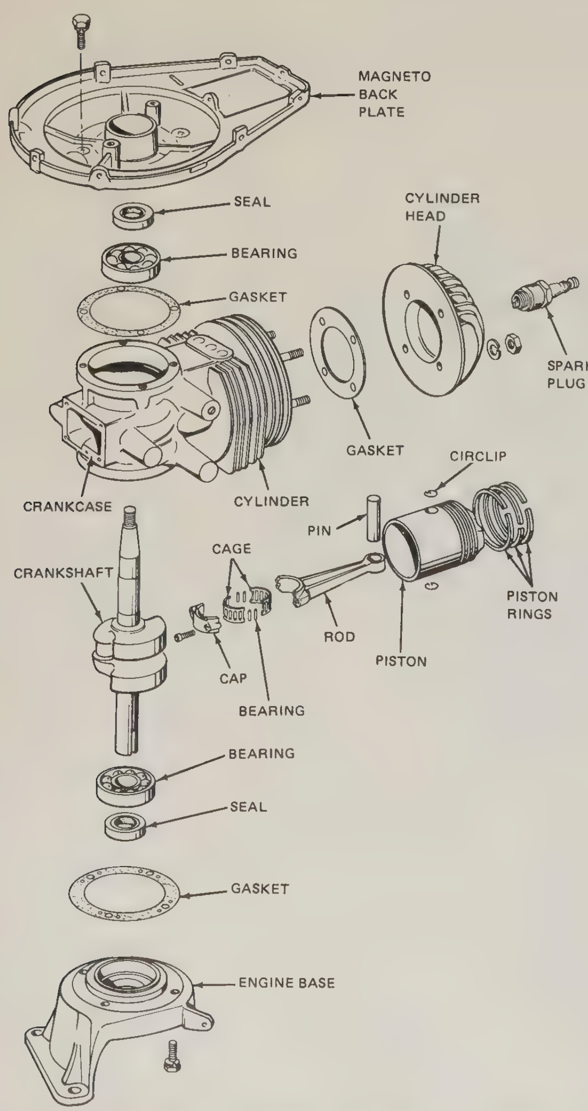


FIG. 2-6 Completely disassembled view of a single-cylinder two-cycle engine. *(Jacobsen Manufacturing Company)*

the engine is pictured as if it had been cut in two (sections) to show what it looks like inside. It appears to be cut in half like an apple.

Another type of picture prepared to show the inside of a part is a cutaway view. Figure 2-5 is a cutaway view of a chain saw. There is also the exploded view, such as shown in Fig. 2-6, which pictures the parts used to make a one-cylinder air-cooled engine for a power lawn mower. Notice that the parts are laid out in the order in which they go together to make the assembly. Exploded views are very helpful, because they show you the order in which parts are to be put together.

Figure 2-7 is a line drawing, so called because it is made up of lines. The picture shows a technician checking the lawn-mower engine.

Figure 2-8 is a still different kind of picture. It is called a phantom view. In the illustration, various parts are painted in as though they were transparent. It is as though you can see through them so you can look into the inside of the engine. This is the reason

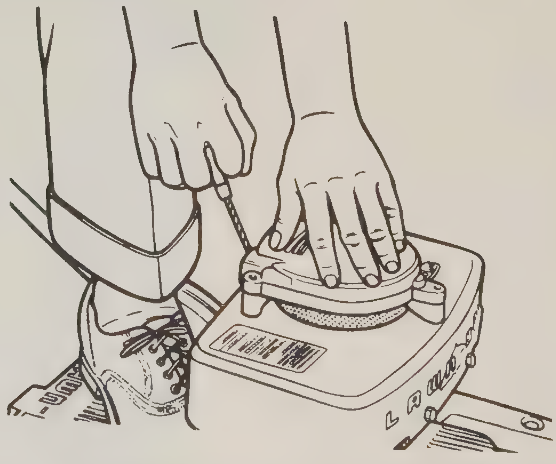


FIG. 2-7 Line drawing showing how to check engine compression by slowly pulling the engine through the compression stroke with the starter rope.

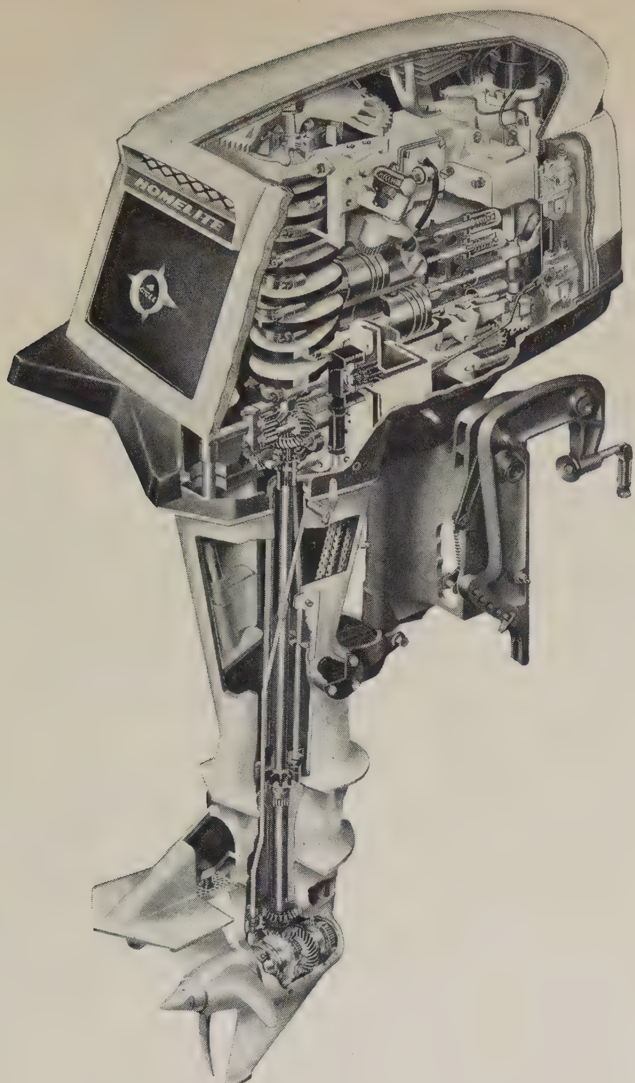


FIG. 2-8 Phantom view of a four-cycle outboard engine. (*Homelite Division of Textron, Inc.*)

for the name. You can see through the parts, almost as though they were phantoms, or ghosts.

You will find many pictures of all these types in this book and also in shop manuals issued by the various engine manufacturers. The purpose of the illustrations is to help you understand how small engines, and the equipment on which they are used, are constructed, how they work, and how to repair them.

REVIEW QUESTIONS

1. What are the six basic steps in any small-engine job?
2. Name four measurements you might make on an engine.
3. In small-engine terms, what does "tear down" mean?
4. Name three machining jobs you might do on an engine.
5. What does the word "specs" mean?
6. Where do you find specs?
7. Name four types of illustrations used in shop manuals and in this textbook.

SELF PROJECTS

1. Look at a small-engine service manual. At the front, on the first or second page, there is a quick reference index. Find out how to use it.
2. Now make a list of the sections listed in the quick reference index.

Chapter 3

Safety in the Shop

After studying this chapter, you should be able to:

1. **Explain what good safety practice in the shop means**
2. **Explain what you should do in an emergency**
3. **Discuss fire prevention**
4. **Describe the various types of fire extinguishers and the types of fires they are to be used on**
5. **List the safety guidelines you should follow in the shop**

○ 3-1 SAFETY IS YOUR JOB Safety in the shop means protecting yourself and those around you from danger or injury. Safety is everybody's job. It is *your* job. When working in the shop, you are being "safe" if you are protecting your eyes, your fingers, your hands—your whole body—from danger at all times. And, just as important, safety also means looking out for those around you.

○ 3-2 LAYOUT OF THE SHOP The first thing you should do when you go out into a shop is to find out where everything is located. A typical layout for a small lawn-mower repair shop is shown in Fig. 3-1. See what the layout of your shop is. You should do this regardless of whether it is a school shop or a shop where you are going to work.

You should note where the machine tools—the power tools—are located. Read the warning and caution signs posted on the walls. They are posted to warn you against potential danger. Notice where the fire extinguishers are located. You might need to get a fire extinguisher quickly some day.

○ 3-3 EMERGENCIES If there is an accident and someone gets hurt, notify your instructor at once! Your instructor will make the decision what to do—whether to call the school nurse, a doctor, or an ambulance. If there is a fire, get help at once. The quicker you get at a fire, the easier it is to control.

○ 3-4 FIRE PREVENTION Gasoline is such a familiar item in the shop that people often forget that it can be extremely dangerous. A spark or lighted match in a closed place filled with gasoline vapor can cause an explosion. Even the spark from a light switch can set off gasoline vapors. There have been cases in which employees washed the shop floor with gasoline—with the doors closed—and then turned off the lights. The spark from the light switch set off an explosion of gasoline vapor that destroyed the

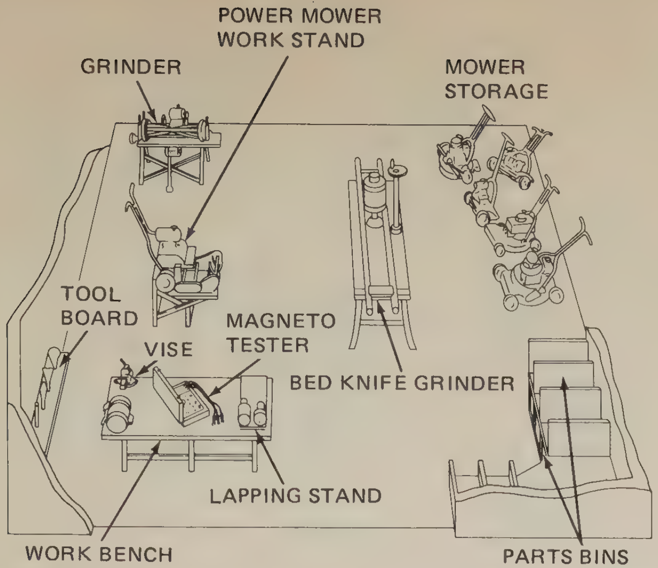


FIG. 3-1 A typical layout for a lawn-mower repair shop. *(Lawn Boy Division of Outboard Marine Corporation)*

building and also injured or killed the employees (Fig. 3-2).

It also is dangerous to pour gasoline down floor drains. Gasoline can form vapors in the sewer line. These vapors could be set off by a lighted match or cigarette thrown down a drain.

To prevent explosions, keep the shop doors open or the ventilator system going if there is gasoline vapor around. Wipe up spilled gasoline at once, and put the rags outside to dry. Never light or smoke cigarettes around gasoline. If you are working on a small engine with a leaky carburetor, fuel line, or fuel pump, catch the leaking gasoline in a container or with rags. Then put the rags outside as soon as possible. Fix the leak right away. Be very careful to avoid

FIG. 3-2 Gasoline vapors are highly explosive.

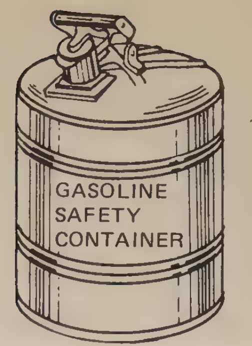


FIG. 3-3 An approved type of safety container for gasoline.

sparks around gasoline. Store gasoline in an approved safety container (Fig. 3-3). Never keep gasoline in a glass jug or a household type of thin plastic jug. The jug could break and cause an explosion or fire.

Oily rags are another possible source of fire. The oil on the rags might cause so much heat to develop that the rags ignite spontaneously, or catch fire. This is called spontaneous combustion. It results from a chemical action that produces heat and fire. Oily rags and waste should be put into special closed metal containers where they can do no harm.

○ 3-5 TAKING CARE OF YOURSELF IN THE SHOP

Some people say, "Accidents will happen!" Safety experts do not agree. They say, "Accidents are caused"—caused by carelessness, by inattention to the job at hand, by the use of damaged or incorrect tools, and sometimes by just plain stupidity. To keep accidents from happening, follow these simple safety guidelines:

1. Work quietly and give the job your undivided attention.
2. Keep your tools and equipment under control.
3. Never indulge in horseplay or other foolish activities. You could cause someone to get seriously hurt.
4. Do not put sharp objects, such as screwdrivers, in your pocket. You could cut yourself or get stabbed.
5. Make sure your clothes are suitable for the job. Dangling sleeves or ties can get caught in machinery and cause serious injuries. Do not wear sandals or open-toe shoes. Wear full leather shoes with nonskid rubber heels and soles. Steel-toe shoes are best for shopwork.
6. Wipe excess oil and grease off your hands and tools so that you can get a good grip on tools or parts.

7. If you spill oil or grease, or any liquid, on the floor, clean it up so that no one will slip and fall.

8. Never use compressed air to blow dirt from your clothes, and never point a compressed-air hose at another person. Flying particles could put out an eye.

9. Always wear goggles or a face shield on any job where there is danger from flying particles (Fig. 3-4).

10. Watch out for flying sparks when you are using the grinding wheel or welding. The sparks can set your clothes on fire.

11. To protect your eyes, wear goggles when using chemicals, such as solvents. If you get a chemical in your eyes, wash them out with water and see the school nurse or a doctor at once.

12. Always use the right tool for the job. The wrong tool could damage the part being worked on and could also cause you to get hurt.

13. If you have to lift a heavy object, do it right. You can strain your back and injure yourself if you try to lift too much or lift improperly (Fig. 3-5). When you must lift or move a heavy object, get help.

14. Never siphon gasoline from a tank using your mouth and a piece of hose. Swallowing even a small amount of gasoline can cause serious respiratory infection and pneumonia. Also, the lead in gasoline is poisonous. If you should get some gasoline in your mouth, spit it out, and rinse out your mouth several times. Avoid taking deep breaths. If you swallow some gasoline, do not try to vomit. Instead, get medical help at once. Your life may depend on it!

FIG. 3-4 Always wear safety glasses, goggles, or a face shield when using a bench grinder.

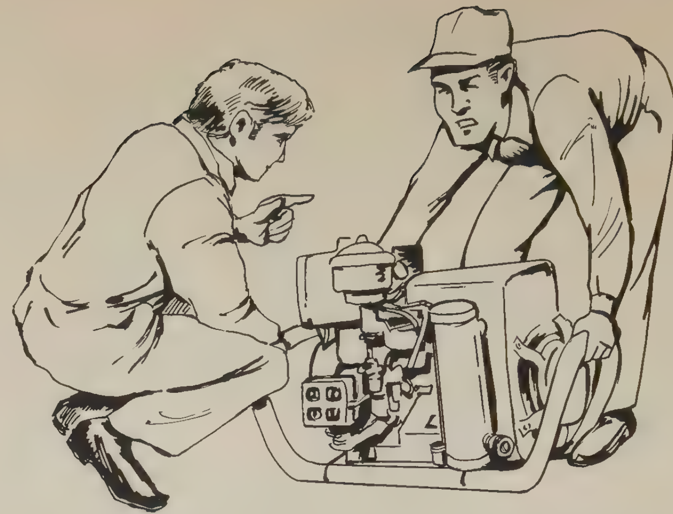


FIG. 3-5 When you must lift or move a heavy object, get help.

CAUTION: Never run an engine in a closed garage that does not have a ventilating system. The exhaust gases contain carbon monoxide. Carbon monoxide is a colorless, odorless, tasteless, poisonous gas that can kill you! Enough carbon monoxide to kill you can accumulate in a closed one-car garage in only three minutes.

REVIEW QUESTIONS

1. What is the first caution to observe when you are using a grinding wheel?
2. What is wrong with using gasoline to clean the floor or workbench with the shop doors closed?
3. Why are oily rags dangerous?
4. What is wrong with operating an engine in a shop or room with the garage doors closed?
5. How many fire extinguishers are there in your shop, and where are they located?
6. Why should you never store gasoline in a glass or thin plastic jug?
7. Why must you never point the compressed-air hose at another person?

SELF PROJECT

Make the floor plan of the school shop, showing the various working areas and the location of the workbenches and power equipment.

4
Chapter

Fasteners

After studying this chapter, you should be able to:

1. **Discuss screw threads and explain thread pitch, series, and classes**
2. **Explain how bolts and screws are marked to indicate their strength**
3. **Explain how metric threads differ from USCS threads**
4. **List the various types of nuts, screws, and bolts and common applications for each**
5. **Describe the various types of locking devices**

○ 4-1 TYPES OF FASTENERS Fasteners include screws, bolts, studs, nuts, cotter pins, lockwashers, snap rings, keys, rivets, and safety wire. We discuss each of these in this chapter.

○ 4-2 MACHINE SCREWS AND BOLTS Screws, or machine screws, enter threaded holes, but bolts need nuts. However, as far as appearance is concerned, screws and bolts may be very similar. A great variety of screws and bolts are used on the engine and engine-driven equipment. Most bolts have hexagonal or six-sided heads, as shown in Fig. 4-1. Screws may also have hexagonal (usually called *hex*) heads, but they are also supplied with other provisions for driving. Wrenches and screwdrivers used with screws and bolts are discussed in Chap. 5.

○ 4-3 SCREWS The term "machine screw" refers to the type of fastener which is driven, or turned, into drilled and threaded holes in metal parts. The screw is turned down into the threaded holes to hold another part in place. There are many types of screws.

○ 4-4 BOLTS Bolts require nuts, as shown in Fig. 4-1. The bolt is put through holes in parts to be attached to each other, and the nut is then turned onto the bolt.

○ 4-5 STUDS Another type of bolt is the stud. The stud does not have a head. It is essentially a piece of threaded rod. A common use is to fasten the cylinder head to the cylinder. Several studs are screwed into the threaded holes around the cylinder. The cylinder head is set down over the stud bolts, and nuts are used to hold the head in place.

○ 4-6 NUTS Various nut shapes are shown in Fig. 4-2. The slotted and castle, or castellated, nuts are used with cotter pins. Other nuts are used with lockwashers. The differences are explained later.

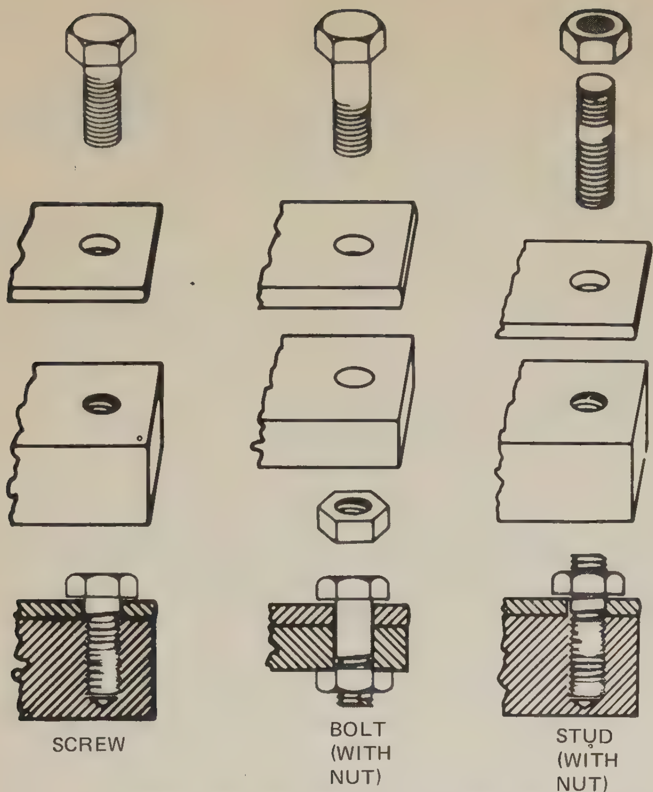


FIG. 4-1 Screw, bolt, and stud. Top shows the attaching parts separated, but aligned for assembly. Bottom shows the parts together, in sectional view.

Cotter pins and lockwashers prevent the nuts from working loose and dropping off. Lockwashers are also used under the heads of bolts and screws to keep them from loosening.

Another locking method uses two nuts. The second nut is turned down on and tightened against the first nut. The second nut, sometimes called a "jam nut," locks the first nut in place and keeps it from working loose.

The speed nut, shown in Fig. 4-2, is formed from sheet metal and is properly called a *Tinnerman nut*. It is quickly installed by pressing it down into place on the stud or bolt.

Some nuts have a "built-in" locking feature, as shown in Fig. 4-3. The self-locking nut (Fig. 4-3*a*) has

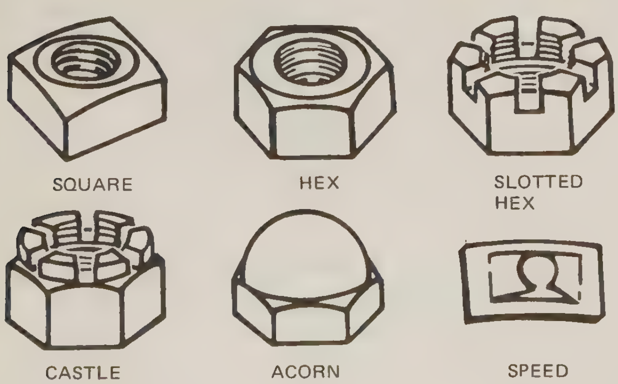


FIG. 4-2 Several common nuts used on small engines.

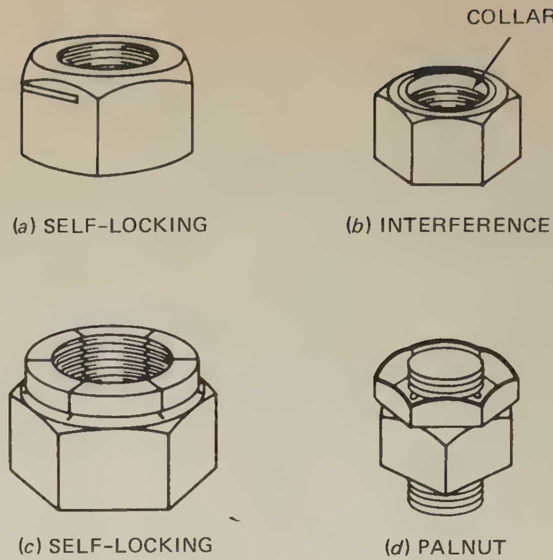


FIG. 4.3 Self-locking nuts.

a slot cut in the side, and the upper threads are somewhat distorted. When the nut is turned down on the bolt, the separated sections of the nut are drawn slightly together. This spring effect produces friction on the threads that acts to prevent nut movement.

The self-locking nut with the vertical slots (Fig. 4-3*c*) is made with the inner diameter of the upper sections slightly smaller than the bolt diameter. The upper segments of the nut press against the bolt threads to hold the nut in position. The Palnut (Fig. 4-3*d*) is a single-threaded lock nut.

The interference nut (Fig. 4-3*b*) has a collar of fiber or soft metal. The bolt threads cut threads in the fiber or soft metal as the nut is turned on the bolt. The additional material jams in the bolt threads to keep the nut from loosening.

○ 4-7 THREADS Screws, bolts, and studs all have external threads, or threads on the outside. Nuts and threaded holes have threads on the inside. Nuts and bolts come in many sizes, from very small to very large. Large nuts and bolts have coarse threads, which means that there are only a few threads per inch. You can count the number of threads on a bolt. Just measure 1 inch from the end of the bolt and count the number of threads. There are also other measurements of a bolt. These include the length of the bolt, diameter of the bolt and length of the thread.

○ 4-8 PITCH Pitch is the number of threads per inch. In addition to using a ruler to count the number of threads per inch, you can also use a thread gauge. To use the gauge, find the blade that has the proper number of teeth to fit the threads, as shown in Fig. 4-4. The blade is marked with the pitch, or number of teeth per inch.

Screw threads are puzzling, but you should know about them. A screw that is ¼ inch in diameter can have 20, 28, or 32 threads per inch. Now let us find out

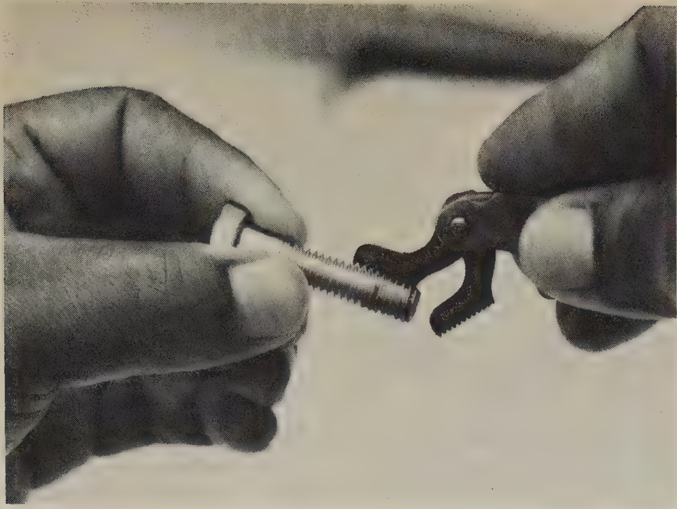


FIG. 4-4 Using a thread gauge.

how to tell the difference. You cannot put a ¼-inch 20-thread nut on a ¼-inch 28-thread bolt.

○ 4-9 THREAD SERIES There are three thread series: coarse, fine, and extrafine. By "coarse," "fine," and "extrafine," we mean the pitch, or number of threads in an inch. A ½-inch bolt, for example, could have coarse threads (13 threads per inch). Or a ½-inch bolt could have fine threads (20 threads per inch) or extrafine threads (28 threads per inch). A coarse thread shortens the disassembly and reassembly time, because fewer turns are required to remove or install it. The fine and extrafine threads are smaller than the coarse threads. The fine and extrafine threads are used where greater bolt strength and additional accuracy of assembly are required.

○ 4-10 THREAD CLASSES There are three thread classes. The difference is in the closeness of fit. Class 1 has the loosest fit and is easiest to remove and install, even when the threads are dirty and somewhat battered. Class 2 has a tighter fit. Class 3 has a very close fit. An external thread, which is used on a bolt, screw, or stud, is called an A thread. An internal thread, which is used in a nut or threaded hole, is called a B thread.

○ 4-11 COMPLETE THREAD DESIGNATION Now let us put together all that you have learned about threads. A thread is designated by size, pitch, series, and class. For example, suppose you have a ¼-20 UNC-2A bolt. This means that the bolt is ¼ inch in diameter, that it has coarse threads (20 threads per inch), and that the thread is an external class 2 thread.

Here is why it is important to know about threads: You cannot use a ¼-28 UNF-2A bolt with a ¼-20 UNC-2B nut because the threads do not match. Not only the bolt size but also the threaded pitch must be the same for a bolt or screw to fit a nut or a threaded hole.

○ 4-12 TYPES OF BOLTS AND SCREWS Bolts and hex-head screws are made of materials of different strengths. The table in Fig. 4-5 shows the head markings that tell the quality of the bolt or screw and how much tightening one manufacturer recommends for that size bolt or screw. High-quality bolts and screws are more expensive and are used only where added strength is necessary.

○ 4-13 OTHER TYPES OF SCREWS The setscrew, shown in Fig. 4-6, is a special type of screw. Its purpose is to fasten a collar, gear, or similar part to a shaft. The setscrew is turned down in a threaded hole in the collar or gear until the inner end contacts the shaft. The inner end, or point, of the setscrew "bites"

BOLT OR SCREW SIZE	GRADE 2	GRADE 5	GRADE 8
1/4–20 1/4–28	70 in. lb. 85 in. lb.	115 in. lb. 140 in. lb.	165 in. lb. 200 in. lb.
5/16–18 5/16–24	150 in. lb. 165 in. lb.	250 in. lb. 270 in. lb.	350 in. lb. 30 ft. lb.
3/8–16 3/8–24	260 in. lb. 300 in. lb.	35 ft. lb. 40 ft. lb.	50 ft. lb. 60 ft. lb.
7/16–14 7/16–20	35 ft. lb. 45 ft. lb.	55 ft. lb. 75 ft. lb.	80 ft. lb. 105 ft. lb.
1/2–13 1/2–20	50 ft. lb. 70 ft. lb.	80 ft. lb. 105 ft. lb.	115 ft. lb. 165 ft. lb.
9/16–12 9/16–18	75 ft. lb. 100 ft. lb.	125 ft. lb. 165 ft. lb.	175 ft. lb. 230 ft. lb.
5/8–11 5/8–18	110 ft. lb. 140 ft. lb.	180 ft. lb. 230 ft. lb.	260 ft. lb. 330 ft. lb.
3/4–10 3/4–16	150 ft. lb. 200 ft. lb.	245 ft. lb. 325 ft. lb.	350 ft. lb. 470 ft. lb.

FIG. 4-5 Grade and torque for various sizes of bolts and screws. *(Kohler Company)*

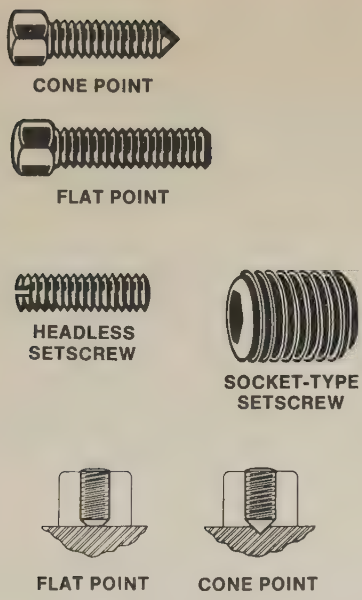


FIG. 4-6 Types of setscrew points.

into the shaft and holds the collar or gear in the set position. Figure 4-6 shows various types of setscrew points. Often the shaft has a flat side machined on it for the setscrew to bite into. This makes it easier for the setscrew to prevent the gear, or collar, from slipping on the shaft.

One special type of screw cuts its own threads. This is a self-tapping screw. The end of the screw is somewhat smaller and may have one or more slots cut in it. These slots form cutting edges on the threads so that, when the screw is turned into the hole, threads are cut in the hole. The end of the screw acts like a tap to cut its own threads.

There is another special type of screw that not only cuts its own threads but also drills the hole. The point of the screw is formed into a drill and tempered. When the screw is used, only one operation is required, because it drills, taps the hole, and fastens itself.

○ 4-14 OTHER TYPES OF FASTENERS There are other types of fasteners used in an engine besides screws and bolts. Lockwashers, cotter pins, and safety wire are used with screws and bolts to keep them from loosening or coming off completely. Rivets are used to permanently fasten two or more pieces together. Keys and splines are used to keep collars or gears from slipping on a rotating shaft.

○ 4-15 LOCKWASHERS Lockwashers, shown in Fig. 4-7, are generally placed between the nut or screwhead and a flat washer. The edges left by the split in the plain lockwasher cut into the nut or screwhead and keep it from turning and loosening. The toothed lockwashers provide many edges to improve the locking effect. In some assemblies, the flat

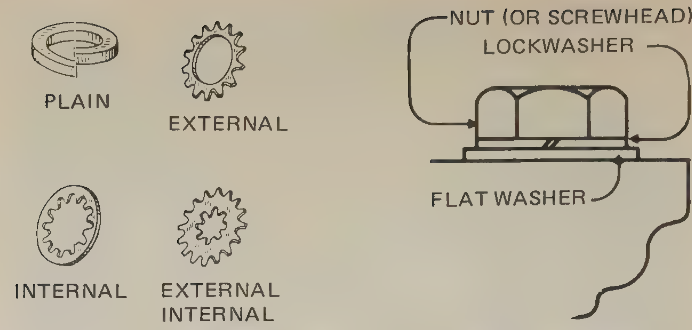


FIG. 4-7 Lockwashers (left) and a plain lockwasher installed between a flat washer and a nut or bolt (right).

washer is not used. A lockwasher is placed between the nut or screwhead and the machine part.

○ 4-16 COTTER PINS Cotter pins, shown in Fig. 4-8, are used with slotted and castle nuts. The bolt has a hole through which the cotter pin passes. To use the pin, the nut is tightened, and the nut slots are lined up with the hole in the bolt. Then the cotter pin is inserted and the two legs of the pin are bent as shown.

To remove the cotter pin, straighten out the two legs and pull it out with a pair of pliers. Once the inexpensive cotter pin has been used, throw it away. Its legs may break if bent again.

○ 4-17 RIVETS Rivets are metal pins used to fasten two parts together more or less permanently. In a garden tractor or other small vehicle, rivets may be used to hold the brake lining on the brake shoes. They also are used to keep the clutch lining in place and to hold linkage together.

One end of the rivet has a head. After the rivet is in place, a driver, or hammer-and-rivet set, is used to form a head on the other end. In blind holes, where one end of the rivet cannot be reached for flattening, a Pop rivet can be used.

Rivets are usually removed by cutting off one end with a chisel. They can also be driven out with a punch or drilled out.

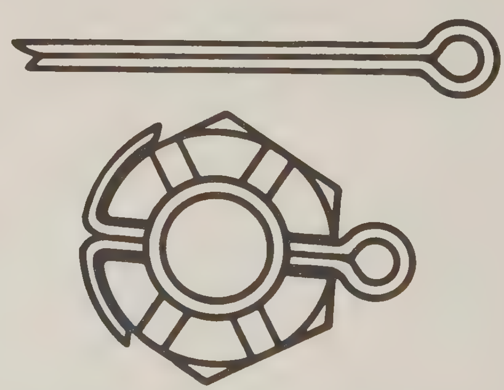


FIG. 4-8 Cotter pin before installation (top) and after installation through the hole in the bolt and the slot in the nut.

○ 4-18 KEYS AND SPLINES Keys and splines are used to lock gears, pulleys, collars, and other, similar parts to shafts. Figure 4-9 shows a typical key installation. The key is a wedge-shaped piece of metal. It fits into slots, called keyways, cut into the shaft and collar or pulley or gear being installed on the shaft. The key locks the shaft and collar so they rotate together.

To install the key, as shown in Fig. 4-9, place the key into the keyway in the shaft. Then slide the collar over the key until it fits in place. If the collar or gear is to be installed on the end of the shaft, the keyway often extends to the end of the shaft. With this type of assembly, the collar is placed on the shaft so that the keyways match. Then a wedge-shaped key is driven into the two keyways for a tight fit. No other holding device is required to fasten the collar firmly to the shaft.

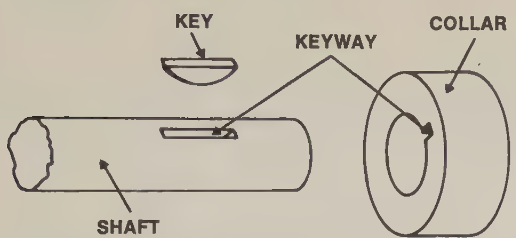


FIG. 4-9 A key fits into slots, called keyways, to hold two parts in place.

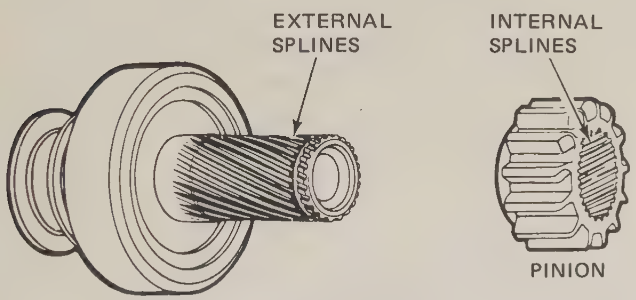


FIG. 4-10 Internal and external splines.

Splines, shown in Fig. 4-10, are internal and external teeth cut into both the shaft and the installed part. When the pinion, gear, pulley, or collar is installed, the use of splines is the same as having a great number of keys between the installed part and the shaft. In many mechanisms, the splines fit loosely so that the gear or other part is free to move back and forth endwise on the shaft. The splines force both parts to rotate together. Splines may be curved or straight.

○ 4-19 SNAP RINGS External snap or retaining rings, shown in Fig. 4-11, are used on shafts to prevent endways movement of a gear or collar on the shaft. Internal snap or retaining rings are used in pistons, transmission cases, and similar parts to keep pins, shafts, or other components in position. The external snap ring must be expanded with special snap-ring pliers so that it slips over the shaft and into the undercut on the shaft. The internal snap ring must be contracted so that it can slip into the hole and into the undercut.

Figure 4-12 shows snap-ring pliers being used to remove the snap ring from a piston. Since snap rings are made of spring steel, they are somewhat difficult to work with. If you do not hold them securely during removal or installation, they have a bad habit of flying across the room.

Snap-ring pliers are made specifically to expand external snap rings, or compress internal snap rings, for removal or installation. These pliers hold the snap ring securely while the ring is under spring tension.

The Tru-Arc retaining rings shown in Fig. 4-11 are a special type of snap ring. They have two lips with holes into which the pin ends of special snap-ring pliers fit. There is less chance of these pliers slipping off the ring during removal or installation. These rings are made for both internal and external installation.

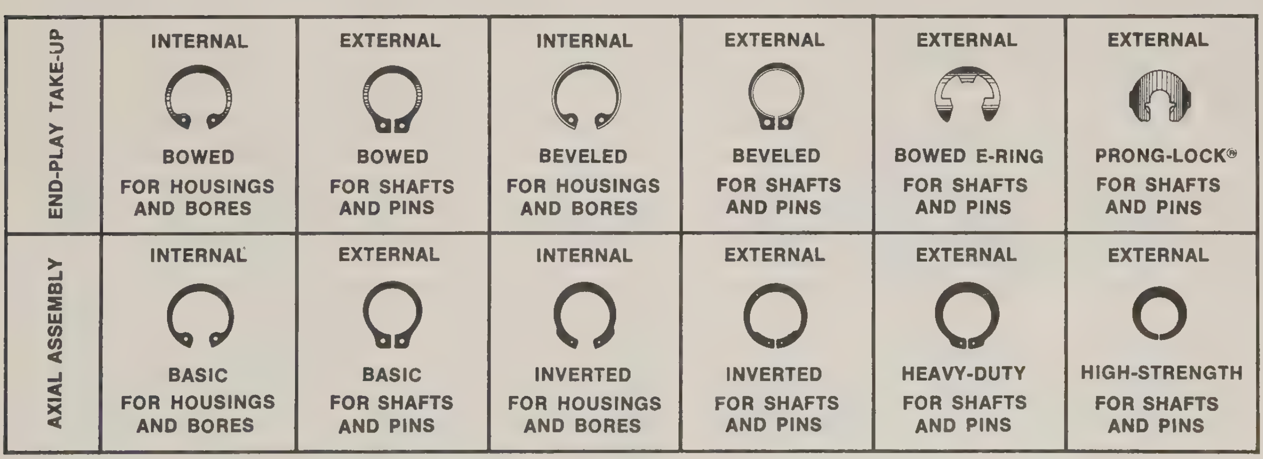


FIG. 4-11 Various types of internal and external Tru-Arc retaining or snap rings. *(Waldes Kohinoor, Inc.)*

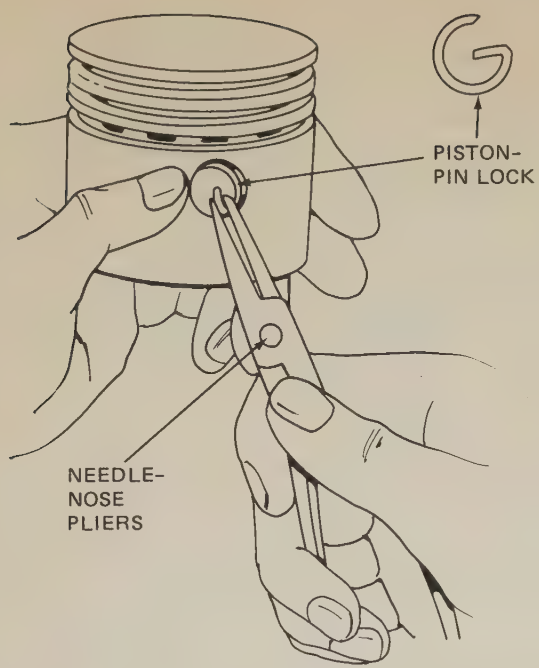


FIG. 4-12 Removing a piston-pin lock, or snap ring, with needle-nose pliers. *(Briggs & Stratton Corporation)*

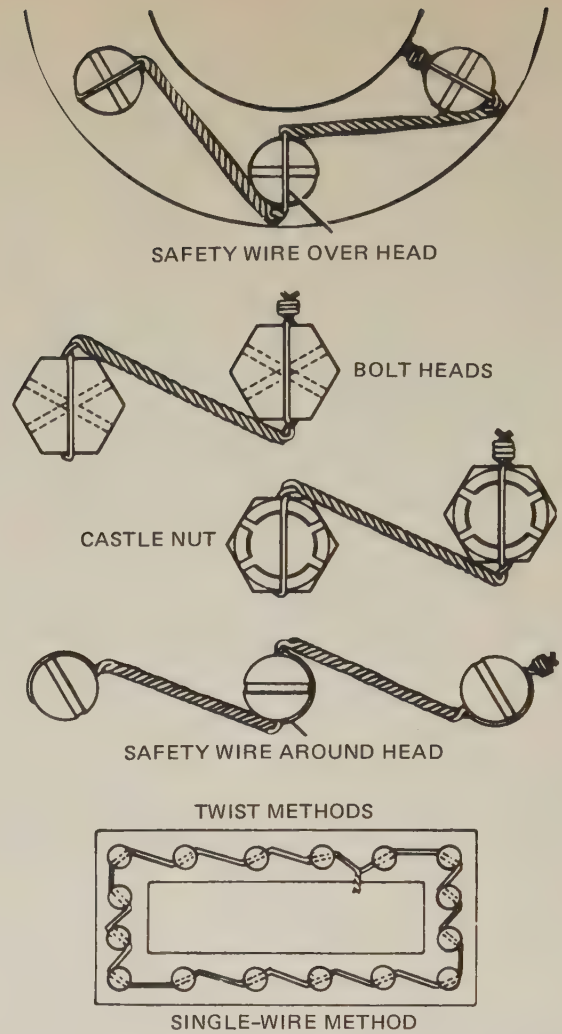


FIG. 4-13 Safety-wiring methods, shown for right-hand threads. For left-hand threads, install wire in opposite direction.

○ 4-20 SAFETY WIRE Small engines, small-engine-powered equipment, and motorcycles generally are considered to vibrate a lot. This heavy vibration can cause nuts, bolts, and other fasteners to work loose. Different types of lockwashers act to prevent threaded fasteners from loosening. But sometimes the vibration in an engine or machine is so severe that no threaded fastener can remain securely tightened. Installing a cotter pin, as we discussed earlier, is one way of safetying, or securing, a nut onto a stud or bolt. Another way is to use safety wire, as shown in Fig. 4-13.

Safety wiring can be used to secure screws, studs, nuts, and bolts by wiring together two or more nuts or bolts. The safety wire is installed so that any tendency of one of the nuts or bolts to loosen is countered by the tightening of the wire and the other nut or bolt.

Two different methods of installing safety wire are used. These are the single-wire plain method and the twist method (shown in Fig. 4-13). For use on small parts that have several closely spaced nuts or bolts, the single-wire method is used. However, the twist method is the more common method of safety wiring. With this method of safety wiring, no more than three widely spaced fasteners should be wired together. Once safety wire is used, it should never be used again.

Safety wire must be installed so that all pull exerted by the wire tends to tighten the nut. The twists should be tight and even. Special wire-twister pliers are available for installing safety wire. If you do not have the special pliers, twist the wire with your hands, not with regular pliers. When you have finished twisting the safety wire, cut off any unused, excess wire. To safety-wire a castle nut, tighten the nut to its minimum specified torque. If necessary, continue tightening the nut until a slot in the nut aligns with a hole in the bolt or stud. Then install the safety wire.

○ 4-21 METRIC BOLTS, SCREWS, AND THREADS The metric system of measurements is described in Chap. 7. Metric bolts, screws, and nuts are measured in millimeters (mm). The threads are also different from the threads used on engines built in the United States. A small-engine mechanic working on both domestic and imported engines needs two sets of fasteners and two sets of wrenches.

The different ways that wrench size for bolts is measured are shown in Fig. 4-14. In both the United States Customary System (USCS) (inch system) and the metric system (millimeter system), the wrench

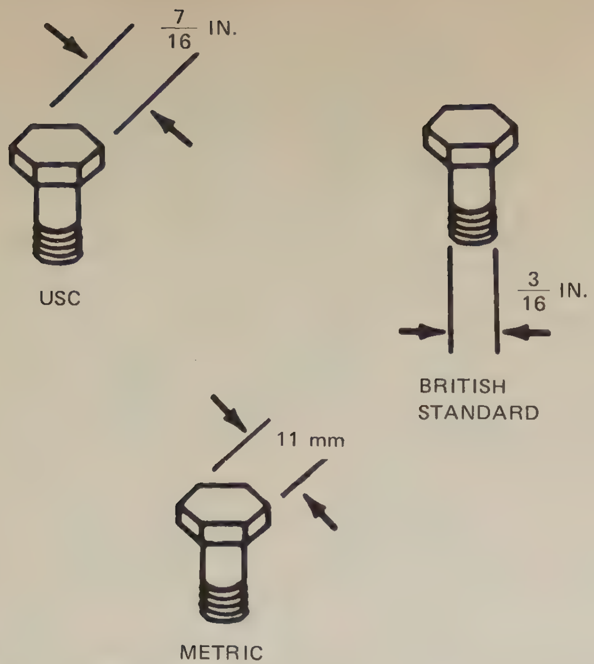


FIG. 4-14 Different ways that wrench sizes for a bolt are determined.

size is determined by measuring across the flats of the bolt head. In past years, the British Standard System was used on engines and motorcycles built in England. In this system, the wrench size is determined by measuring, in inches, across the outside diameter of the threads.

REVIEW QUESTIONS

1. What is the basic difference between a bolt and a stud?
2. Name four kinds of nuts.
3. What is the purpose of the cotter pin? How is it used?
4. What is the purpose of lockwashers?
5. Explain how a rivet works.
6. What is the name of the screw that is used without a nut?
7. What is the most common type of bolt head?

SELF PROJECTS

1. Start a collection of different sizes and grades of hex-head screws and bolts. Remember, bolts and screws can be classified by size, length, pitch, series, and quality. You can measure size and length with a ruler. For pitch you need a thread gauge. The quality is indicated by the markings on the top of the hex head. Tag your bolts and screws to identify them, or mount them on a board with the identification under each.
2. Collect different kinds and sizes of lockwashers.
3. Make a collection of different kinds of nuts.

5
Chapter

Hand Tools

After studying this chapter, you should be able to:

1. **Describe the various types of hand tools**
2. **Explain what a torque wrench is and when it is used**
3. **Demonstrate proper use of the impact driver**

○ 5-1 TYPES OF TOOLS A great variety of tools are used in the modern small-engine shop. Figure 5-1 shows a set of tools for small-engine mechanics. These tools enable the technician to handle any kind of job that comes along with speed and efficiency. Actually, that is the purpose of tools: to enable the mechanic to do the required job as easily and quickly as possible. Whenever a new design of engine or machine comes along, the tool engineers examine it. Then they design the proper service tools that will enable the mechanic to service it correctly.

Despite the fact that there are thousands of different kinds of tools, there are only a few basic types. These include tools for hammering, cutting, measuring, and turning bolts or nuts. We discuss cutting and measuring tools in later chapters. This chapter covers the common hand tools, such as screwdrivers, wrenches, pliers, and hammers.

○ 5-2 SCREWDRIVERS The screwdriver is used to drive, or turn, screws with slotted or recessed heads. The most common type of screwdriver is the one for slotted screwheads shown in Fig. 5-2. Do not use a screwdriver as a prybar, punch, or chisel, because you are likely to break it. Keep the tip properly ground, with the sides practically parallel at the end. If the sides are tapered, the tip tends to rise up out of the screw slot when it is turned.

The blade of a screwdriver is made of tempered steel. This means it has been heat-treated for hardness. If you get it too hot when you are grinding the tip, you will "pull" the temper, or soften it. Keep a cup of water near the grinder. Dip the screwdriver tip in the water every few seconds as you are grinding it to keep the steel from overheating.

Always select the proper screwdriver for the job. The tip should fit snugly in the screw slot. A screwdriver that is too large or too small is hard to use and may damage the screw or part being worked on.

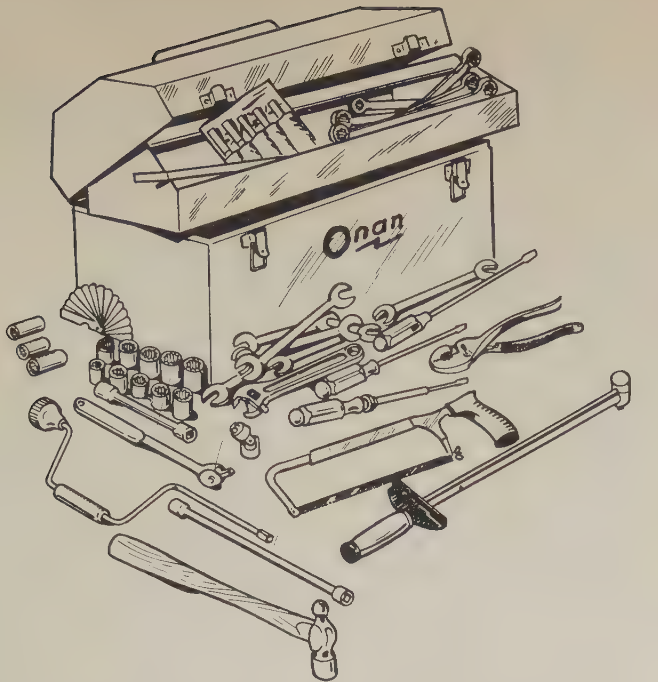


FIG. 5-1 A set of tools for a small-engine mechanic. *(Onan Corporation)*

○ 5-3 SPECIAL SCREWDRIVERS Some screws have what resembles two screw slots at right angles. The Phillips-head screw is one of these. It requires a special screwdriver with a tip to fit the crossed slots as shown in Fig. 5-3. There is less chance that the Phillips-head screwdriver will slip out of the slots and damage the finish of chromed or painted parts. Three sizes of Phillips-head screwdrivers—4-, 6-, and 8-inch [102-, 152-, and 203-mm]—are enough for most shopwork.

The offset screwdriver is a variation of the standard screwdriver. With the offset screwdriver, a screw that is set in an awkward place can be reached and turned. The blade tips are set at right angles so that first, one end of the screwdriver can be used, and then the other can be used to keep the screw turning.

The allen wrench, shown in Fig. 5-4, is a special form of turning tool. It has a hexagonal (six-sided) shape and fits into a hexagonal hole in the head of a screw. This wrench is used for allen screws and many setscrews.

There are many types of special screwdrivers and wrenches, used to turn different types of fasteners.

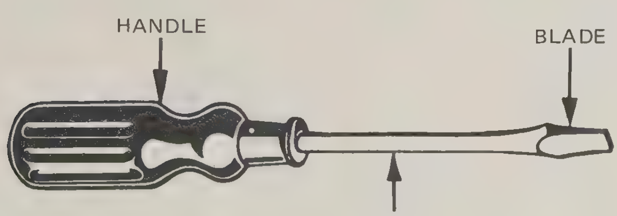


FIG. 5-2 A typical screwdriver.

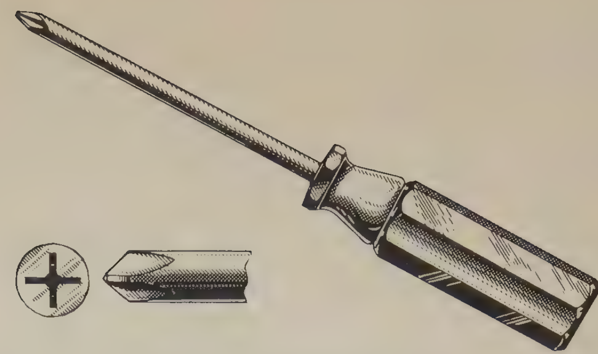


FIG. 5-3 A Phillips-head screwdriver and the slotted head of a Phillips-head screw.

Figure 5-5 shows a number of different types of screwheads and the screwdrivers and wrenches required to drive them.

○ 5-4 WRENCHES Bolt heads and nuts commonly used in machines and engines are of the hexagonal (six-sided) type. They have six flats around the outer surface, as shown in Fig. 5-5. These flats permit the use of a wrench to turn the nut or bolt. Types of wrenches include open-end, box, combination, socket, torque, impact-driver, and adjustable. A variety of wrenches are used in the shop. To work on both domestic and imported engines, you will need two sets of wrenches. Most engines made in the United States use bolts that have heads which are measured in fractions of an inch. These need inch-type wrenches. A 10-piece set (3/8 to 1 inch) will handle most jobs. Imported engines and some domestic engines use metric nuts and bolts. The bolt heads and nuts are measured in millimeters (mm). A 10-piece metric set (6 to 19 mm) will handle most of these. We discuss the metric system in Chap. 7.

○ 5-5 OPEN-END WRENCHES Open-end wrenches, such as shown in Fig. 5-6, are designed to tighten or loosen nuts and bolts. The opening is usually at an angle to the body to permit turning in a tight space. The nut or bolt is turned as far as the space allows. Then the wrench can be flipped over to permit further turning of the nut or bolt. By flipping the wrench after each swing, the nut or bolt can be loosened or tightened satisfactorily.

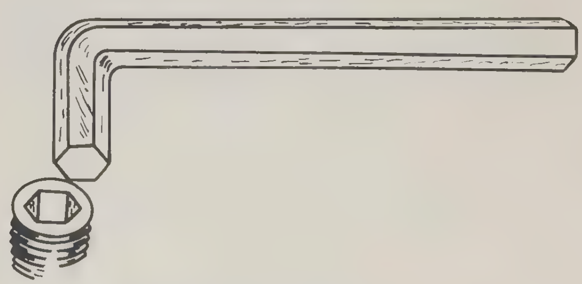


FIG. 5-4 An allen screw and an allen wrench.

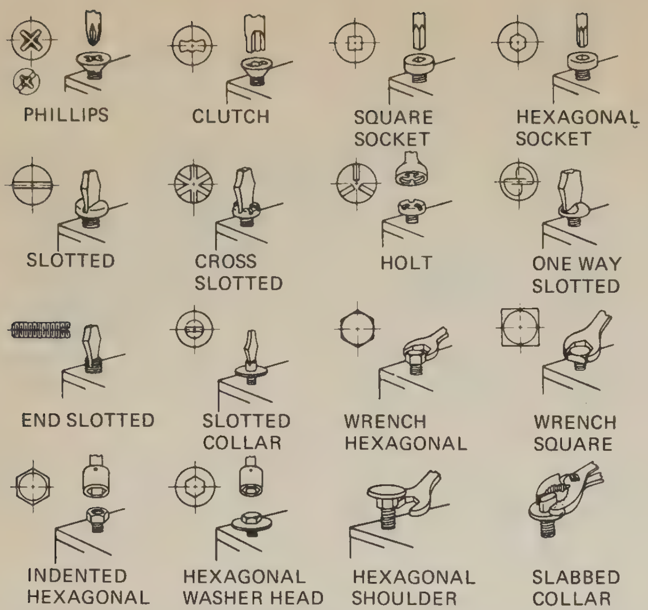


FIG. 5-5 Types of screwdrivers and wrenches required to drive various kinds of screws.

A typical open-end wrench has the open end at an angle of 15° with the handle, as shown at the bottom of Fig. 5-6. A few have a 90° angle for special purposes. The open-end wrench is used by placing the open end over the flats of the bolt head or nut. The wrench handle provides considerable leverage so that the bolt or nut can be tightened or loosened easily.

By turning the wrench after each swing, you can loosen or tighten the nut or bolt satisfactorily. Pull on the wrench rather than pushing it. If you must push, do so with the palm of your hand, keeping your fingers out of the way. In this way, if the nut or bolt suddenly gives, your knuckles will not be hurt.

Make sure that the wrench fits the nut or bolt head snugly. A loose fit throws excessive strain on the wrench. As a result, the jaw may spring or break. The nut or bolt head may also be damaged. Do not use a pipe or another wrench on the end of the wrench for additional leverage. The wrench is designed to withstand the maximum leverage you can apply on its end. Added leverage may cause the wrench to break. Never use a hammer to strike on a wrench except where the wrench has been specifically designed to be used in this manner.

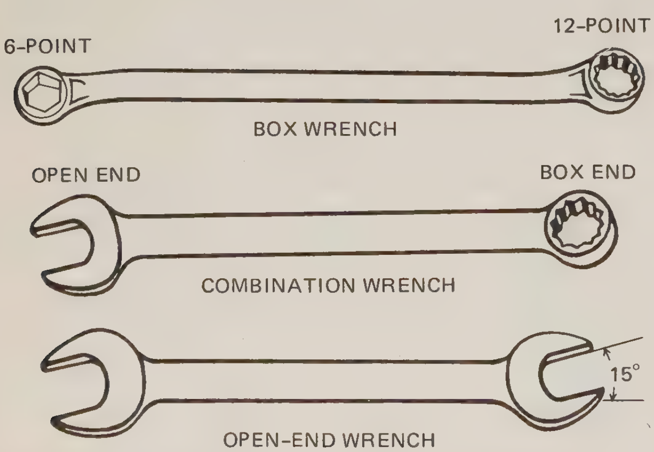


FIG. 5-6 Box, combination, and open-end wrenches.

○ 5-6 BOX WRENCHES Box wrenches, such as shown in Fig. 5-6, do the same job as open-end wrenches. However, the opening for the nut or bolt head surrounds, or "boxes," the nut or bolt head. Box wrenches can be used in very tight spaces because the wrench head is so thin. The wrench cannot slip off the nut. The 12-point box wrench is now used almost everywhere. It has 12 notches in the head. A nut or bolt can be turned even where there is a swing of only 15 degrees to the handle. This provides added clearance for your hand.

A combination wrench has a box wrench on one end and an open-end wrench on the other (Fig. 5-6). The box wrench is more convenient for the final tightening or breaking loose of a nut or bolt. It is less convenient for otherwise turning the nut or bolt. The box must be lifted completely off and then placed back on for each swing. The open-end wrench is more likely to slip off. It is less convenient for the final tightening or breaking loose of a nut or bolt. But it is more convenient for running a nut or bolt off or on. The combination wrench lets the mechanic use first one type and then the other by reversing ends. Both ends of the combination wrench fit the same size nut or bolt.

○ 5-7 ADUSTABLE WRENCH The adjustable wrench, shown in Fig. 5-7, has an adjustable jaw that can be moved back and forth to narrow or widen the

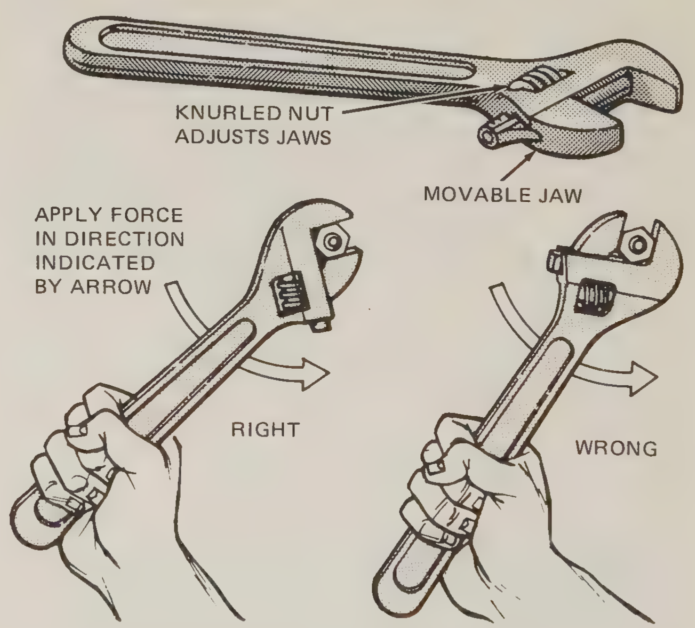


FIG. 5-7 When using an adjustable wrench, pull on the handle so the major load is carried by the stationary jaw, as shown in the lower left illustration. *(Ford Motor Company)*

distance between the jaws. An adjustable wrench can be made to fit many sizes of nut or bolt heads. This tool is not intended to take the place of the regular wrench. But it is handy to have for special jobs or odd sizes of nuts or bolts. When using this wrench, make sure that it is properly tightened on the nut or bolt head. Attach the wrench so that the adjustable jaw will be on the inside of the turning motion, as shown in Fig. 5-7. In this way, the pulling pressure will keep the adjustable jaw tight against the nut or bolt head.

○ 5-8 SOCKET WRENCHES Socket wrenches are somewhat similar to box wrenches, except that the sockets are detachable, as shown in Fig. 5-8, and they are used with special handles. Figure 5-8 illustrates a set of socket wrenches with several types of handles. The sockets fit into the handle selected for the particular job.

The ratchet handle lets the socket be used like a box-end wrench, except that the socket does not have to be lifted from the nut or the bolt at the end of the swing. The handle can be returned to the original position to start a new pull. The socket stays unmoving, as shown in Fig. 5-8. A lever changes the ratchet so the handle can be used to either loosen or tighten the nut or bolt. The handle extension goes between the handle and the socket so you can reach hard-to-get-to places, as when removing spark plugs.

The hinged offset handle, also called nut spinner and breaker bar, lets you turn the socket quickly for such things as running on a nut or a bolt. Then you can swing the handle to the 90-degree position for final tightening. The speed handle serves much the same purpose. It acts like a carpenter's brace-and-bit, but you cannot get the leverage with it that you can with the other handles.

The sliding offset handle is generally used in very cramped spaces. The universal joint can be attached between the handle and the socket. With it you can use any of the handles at an angle to the axis of the socket. All these tools are identified in Fig. 5-8.

○ 5-9 IMPACT DRIVER The impact driver, shown in Fig. 5-9, is also known as the impact screwdriver and as the hand impact tool. When struck with a hammer, the impact driver delivers a forceful turning blow to a frozen screw, nut, or bolt. It is used in small-engine work to loosen seized screws and rusted, corroded, or frozen nuts and bolts. The impact driver is available with ⅜-inch drive or with ½-inch drive. For work in the small-engine shop, ⅜-inch drive is the size most often needed.

To use the impact driver, no electric or air connection is made. A hammer blow delivers the driving force. The correct size screwdriver bit, or socket, is placed on the drive end of the impact driver. Then the head of the impact driver is struck with the hammer. Each blow, or impact, of the hammer turns the bit up to 20 degrees. Loosening seized screws and nuts is the most frequent use of the impact driver. However, it is reversible and can be set to tighten screws and nuts. A wide variety of bits and sockets are available for use with the impact driver.

CAUTION: Always wear safety goggles to protect your eyes when using the impact driver.

○ 5-10 TORQUE WRENCHES On small engines, nuts and bolts must be tightened properly. If they are not tightened enough, they will come loose and something may fall apart. This could cause great trouble, damage to the engine, and possibly a serious accident. If nuts or bolts are tightened too much, they would be strained excessively and could break later, again with disastrous results.

To assure proper tightening of nuts and bolts, you must use a torque wrench. Three types of torque wrenches are shown in Fig. 5-10. The torque wrench is a special form of socket wrench that has a measuring device to indicate the amount of torque, or twist, being applied to a bolt or nut. For example, a specification might call for tightening a bolt to "20–24 pound-feet." This means that you have to put a 20- to 24-pound pull at 1 foot from the bolt. The torque wrench lets you do this accurately. You snap the correct socket on the torque wrench, fit the socket on the bolt head, and pull the wrench handle. As you gradually increase your pull, the scale on the torque wrench registers somewhere between 20 and 24. Then you know you have tightened the bolt correctly. This procedure is called *torquing* the bolt.

○ 5-11 PLIERS A few of the many kinds of cutting and gripping pliers are shown in Fig. 5-11. Each comes in a number of sizes and has a specific purpose. You will use pliers to do many things as you work on a small engine. Although each type is versatile, it can easily be ruined if it is used for the wrong job.

NOTE: Do not use standard pliers to tighten nuts and bolts. This damages the nut or bolt head so that the proper wrench will not fit.

The adjustable combination pliers, shown in the lower left in Fig. 5-11, have been around a long time. At one time or another, they have been called pincers, gas pliers, and slip-joint pliers, among other terms. They have been a common household tool, used for everything from driving tacks to pulling teeth. However, they have a definite place in a mechanic's toolbox. A slip joint holds the two parts of the pliers together. The jaws can be opened or closed to hold large or small parts.

Many combination pliers have two cutting edges at

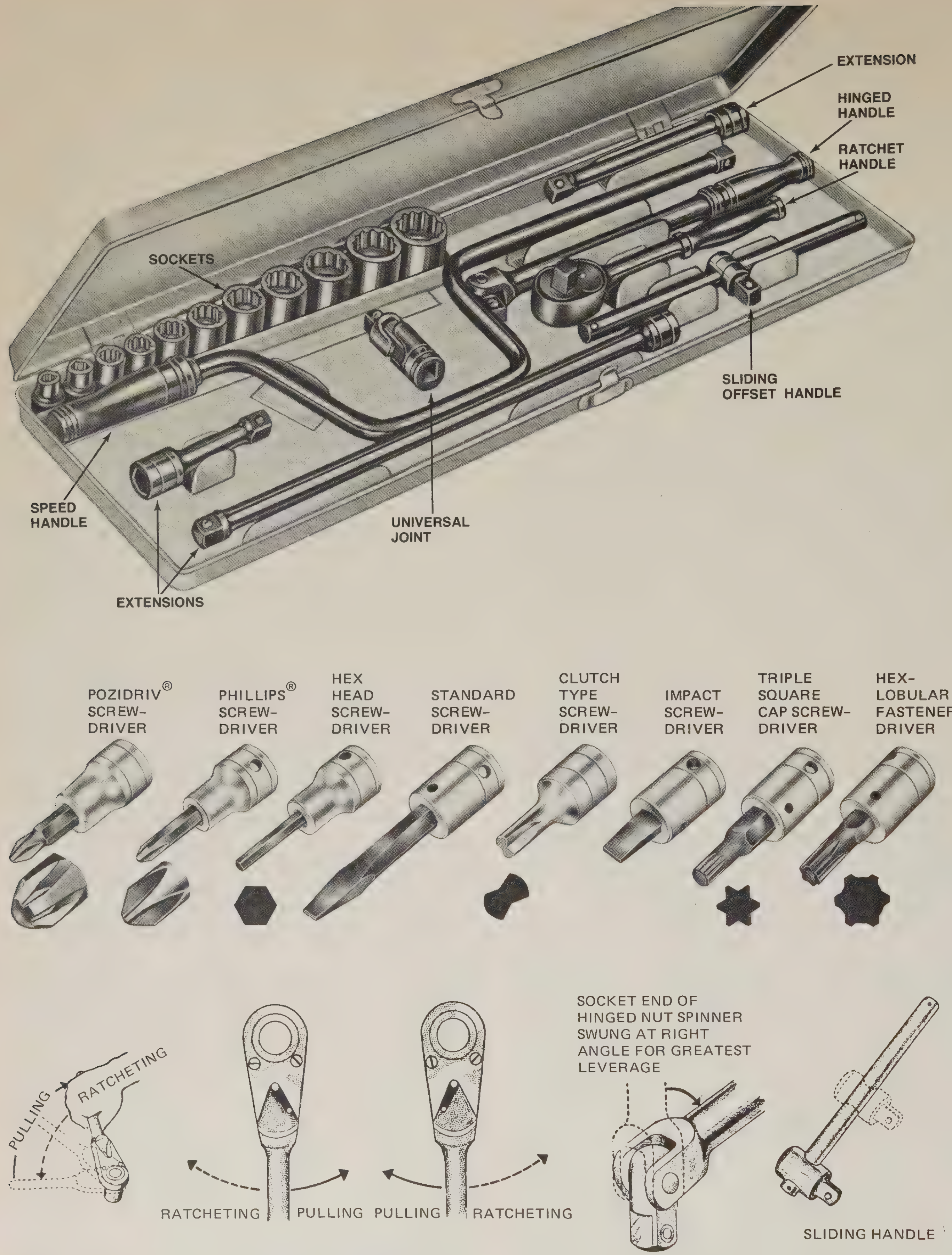


FIG. 5-8 Set of sockets with handles, extensions, screw-drivers, and universal joints. *(Snap-on Tools Corporation)*

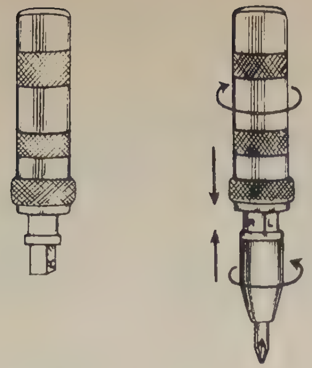


FIG. 5-9 An impact driver.

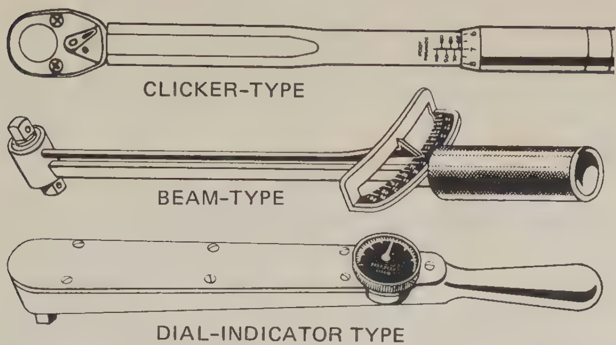


FIG. 5-10 Various types of torque wrenches.

the back of the jaws for wire cutting. However, combination pliers are intended to be used for gripping, such as for holding a small part against a grinding wheel. The lineman's pliers, shown in the top left of Fig. 5-11, should be used for large wire-cutting jobs. Abusive use of combination pliers usually results in damage to the part rather than to the pliers. One such abuse is using them to tighten or loosen screws or nuts. A wrench is the proper tool. Used properly, combination pliers can help you do many things.

Channellock pliers, called interlocking-joint pliers in Fig. 5-11, have a quick adjustment for widening or narrowing the jaws to hold various materials. There are interlocking tongues and grooves on the two parts of the pliers, so that the jaw halves can be moved closer together or farther apart, as shown in the circled inset in Fig. 5-11. These pliers have a wide range of jaw-opening settings. Because the jaws are parallel, Channellock pliers can be used to grip round, square, and flat objects, as well as bolt heads and nuts. Long handles provide good leverage.

A very handy multipurpose tool is the locking pliers-wrench, or Vise-Grip wrench, shown in Fig. 5-12. This type of pliers locks to the work when the handles are squeezed together. The size of the jaw opening is

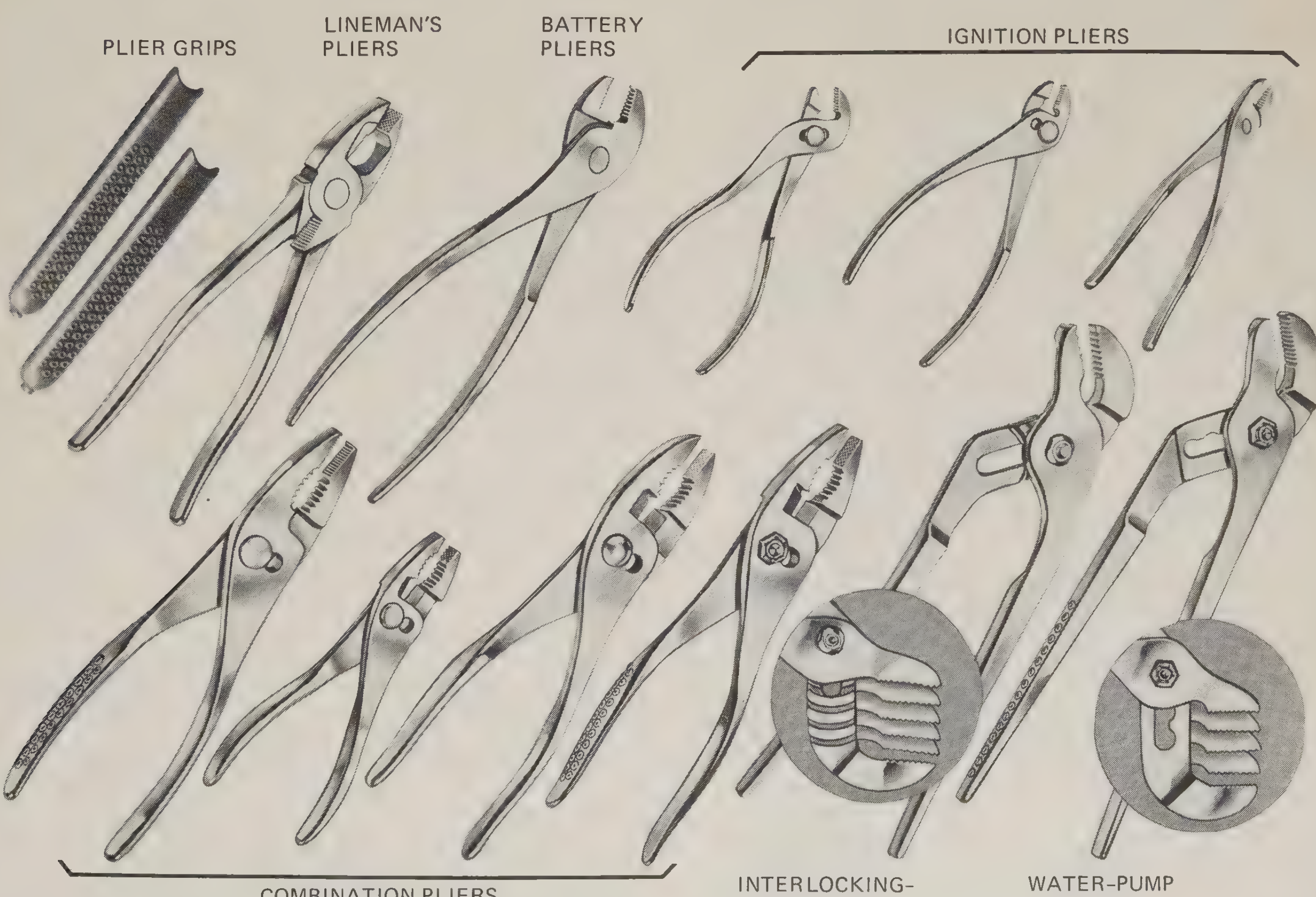


FIG. 5-11 Various types of pliers. *(Snap-on Tools Corporation)*

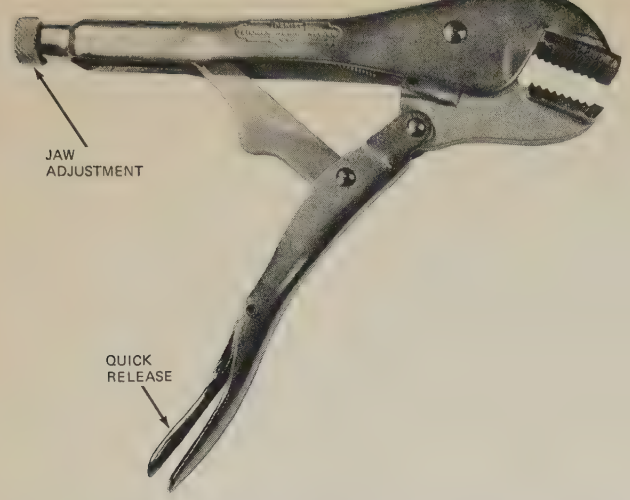


FIG. 5-12 Multipurpose locking pliers-wrench, commonly known as the Vise-Grip wrench. *(Petersen Manufacturing Company, Inc.)*

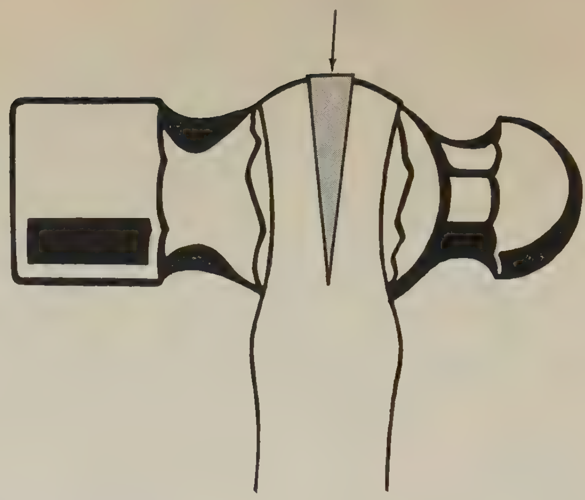


FIG. 5-14 How a hammer head is wedged on a handle.

adjusted by turning the jaw-adjustment screw in the end of the handle. The Vise-Grip pliers can be loosened with the quick release lever on the movable handle, as shown in Fig. 5-12.

○ 5-12 HAMMERS A variety of hammers are used in the shop, as shown in Fig. 5-13. You are probably familiar with the claw hammer, which has a claw

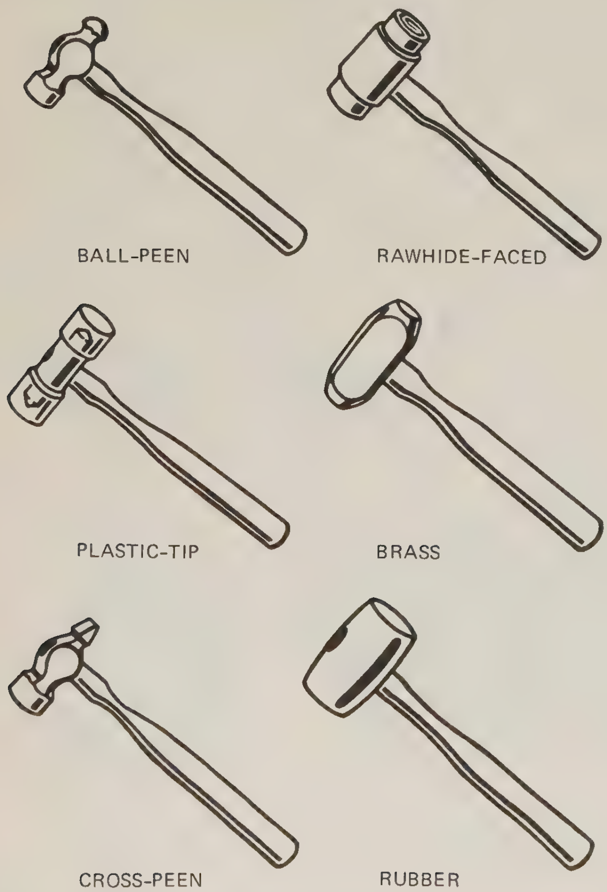


FIG. 5-13 Various types of hammers.

opposite the driving head for pulling nails. This is a carpenter's tool and is not of much use around the engine shop. Instead, the ball peen hammer is used. When using this hammer, grip the handle firmly near its end and swing it so that the face strikes the object squarely.

If the work requiring the use of a hammer is apt to be dented or otherwise damaged by the hard face of the ball peen hammer, then a rawhide-faced hammer should be used.

Check the head of the hammer occasionally to make sure that it is firmly in place on the handle. A small wedge or screw is used to spread the handle and tighten it in the eye of the hammerhead, as shown in Fig. 5-14. If the wedge or screw has become loose, it should be driven tight. Someone could be very seriously hurt if the hammerhead should happen to fly off when the hammer is swung.

REVIEW QUESTIONS

1. Describe a Phillips-head screwdriver.
2. Explain the correct way to use a hammer.
3. Name three types of wrench.
4. What are box wrenches?
5. What are sockets?
6. Name and describe the use of three types of socket handles.
7. What is a torque wrench? How is it used?

SELF PROJECT

Start getting your tools together. Think about the tools you will need to work with. When you start to work, you will be expected to have your own set of hand tools. No tools, no job!

Chapter 6

Cutting Tools

After studying this chapter, you should be able to:

1. **List the cutting tools used in the shop**
2. **Explain the use of a die and tap**
3. **Demonstrate the use of a stud remover**
4. **Demonstrate how to cut and double-flare a piece of tubing**

○ 6-1 TYPES AND PURPOSES OF CUTTING TOOLS Cutting tools have one purpose: to remove metal from the piece of metal being worked on. Cutting tools include chisels, hacksaws, files, taps, and dies. In a sense, all these tools work in a similar way. A chisel has one cutting edge. A hacksaw blade has a hundred or more. A file may have several hundred cutting edges. As a cutting edge is forced along the surface of a piece of metal, it cuts the metal, removing shavings or chips of the metal. Now, let us look more closely at the various cutting tools.

○ 6-2 CHISELS The chisel has a single cutting edge and is driven with a hammer to cut metal. Several different shapes of chisels are shown in Fig. 6-1. Each shape has its special purpose, but the chisel most commonly used is the plain flat cold chisel.

The chisel should be held loosely in the left hand, with the right hand swinging the hammer (or the reverse if you are left-handed). The reason for holding the chisel loosely is one of safety. If the hammer does not strike squarely or if it misses, the left hand will give with the blow and will be less subject to injury.

CAUTION: When using a chisel, always protect your own eyes and the eyes of others in the shop with you. You should always wear goggles, and others near you in the shop should also wear them. You can also set up a chipping shield. Flying chips will hit the shield and will not fly out into the shop. These precautions will protect your eyes and the eyes of other workers or customers. Always make sure that the hammerhead is tight on the handle. Never use a dull chisel or a chisel with a mushroomed head. Such chisels should be ground and tempered.

A chisel that has mushroomed on the end because of repeated hammer blows, should be dressed on a grinding wheel as shown in Fig. 6-2. All the turned-

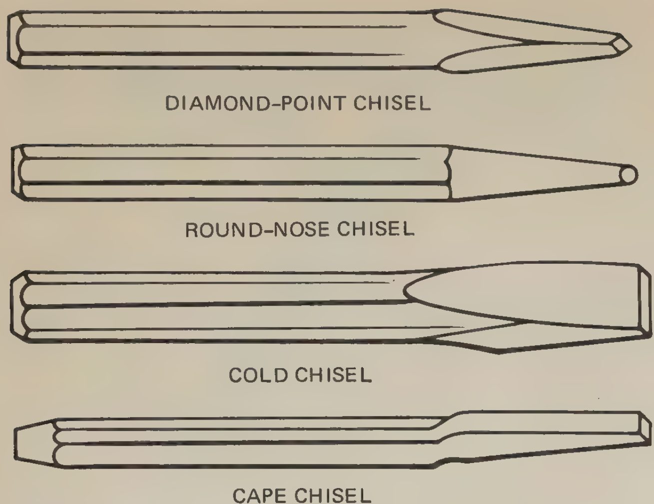


FIG. 6-1 Various types of chisels.

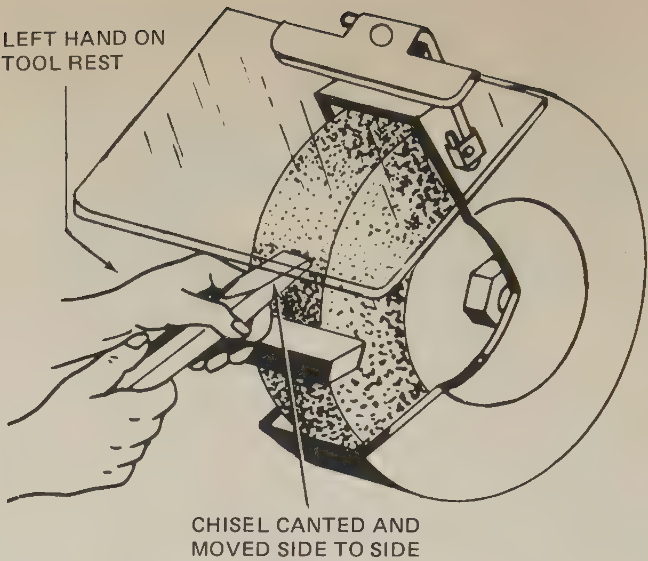


FIG. 6-3 Dressing or grinding a chisel.

over metal should be removed. Otherwise, the metal could break off and fly away as the hammer strikes it. It is difficult to be accurate with a mushroomed chisel, and the flying chips might cut your hand or hurt someone else. Notice also how the cutting edge of the chisel should be dressed on the grinding wheel, shown in Fig. 6-3.

Examine the various chisels shown in Fig. 6-1. The flat chisel is used for cutting sheet metal and for chipping, or removing metal from, flat surfaces. The cape chisel is used for cutting grooves or slots, such as keyways, and for chipping narrow, flat surfaces. The diamond chisel is used for cutting V-shaped grooves. The round-nose chisel is used for cutting round grooves.

Remember the following when using a chisel:

1. Always work with a sharp chisel. A dull chisel will not do good work.
2. Make the hammer blows uniform.
3. Keep the chisel at the proper angle constantly.

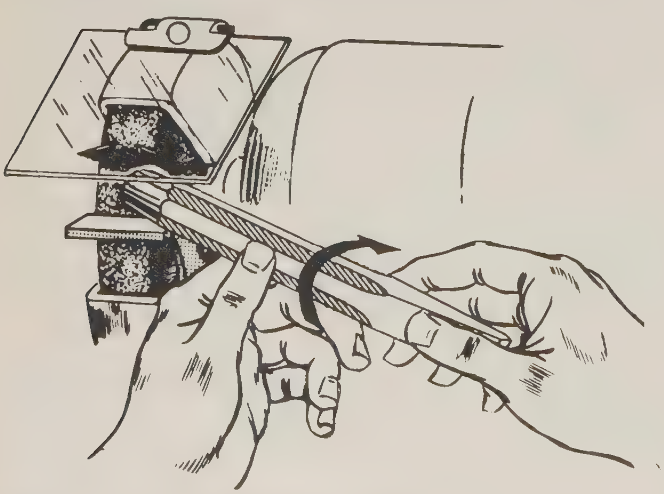


FIG. 6-2 Grinding the mushroom from the chisel head.

4. When chipping cast iron, do not chip all the way to the finishing (back) edge. This might cause a large piece to break off. Instead, stop when you approach the finishing edge. Start a second cut from the finishing edge back toward the first cut. Be careful to ease up on the hammer blows as the second cut nears the first to avoid breaking off a piece of the cast iron.

Now here are a few tips on how to handle jobs you might have to perform using various types of chisels:

To cut sheet metal, place a piece of sheet metal in a vise. Make sure the part to be cut off projects above the jaws. Use soft jaws, as necessary, to protect the sheet metal from marring. Use a flat chisel to shear off metal as shown in Fig. 6-4. Start your cut at one edge and move along the vise jaws. Hold the chisel at a 45° angle to the jaws to secure a good shearing cut.

To cut a keyway in round stock, use soft jaws to clamp a length of round stock in a vise. Place a wood block under the stock to hold it in position in the vise. Use a steel rule and scriber to mark off, on the stock, the width and length of the keyway to be cut.

Select a cape chisel, shown in Fig. 6-1, of the proper width for the cut. Hold the chisel at the proper angle,

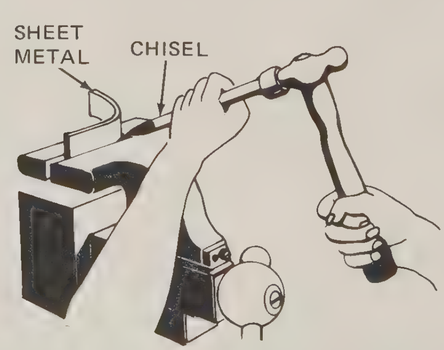


FIG. 6-4 How to use a chisel and hammer to cut sheet metal.

and begin cutting. At the start, the chisel will have to be held so that it cuts down into the metal. Work from both ends toward the middle.

○ 6-3 HACKSAWS Hacksaws are used for cutting metals as shown in Fig. 6-5. A hacksaw is basically a blade held in an adjustable metal frame. The blades are replaceable and are made with from 14 to 32 teeth per inch. There is a proper blade with the correct number of teeth for each job. Using the wrong blade makes the job more difficult and could cause the blade to break.

○ 6-4 FILES A file is like a series of tiny chisels, each with a sharp cutting edge. Files come in many sizes and shapes and have many uses. As the face of the file is moved across a metal piece, the cutting edges or teeth remove shavings from the metal. The coarseness of the file determines how thick the shavings are. The term "cut" is used to designate the coarseness or fineness of the file, as shown in Fig. 6-6.

CAUTION: Be very careful that the handle is firmly in place on the file you are using. Never try to use a file without a handle. The tang is sharp enough to cut you severely if the file "hangs up" while you are filing. If the file catches momentarily on the work and stops moving, your hand will jam against the file tang. Also, never try to use a file as a pry bar. A file is brittle and will break. Flying fragments of the file could cut your hands or face or give you a serious eye injury.

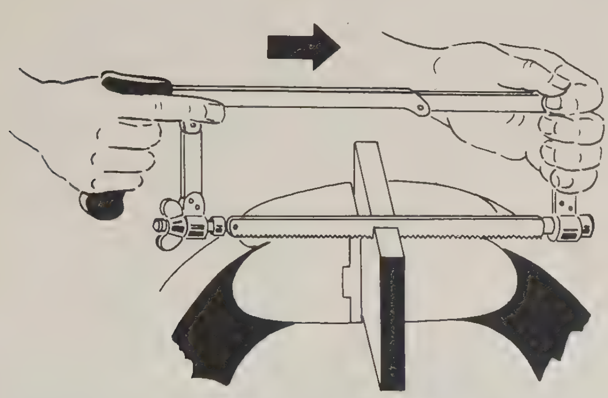


FIG. 6-5 How to hold and use a hacksaw.

There are a number of cautions to be observed in using a file. First, never attempt to use a file without a handle on the tang. Otherwise, your hand might slip, and the tang might be driven into your hand. To install a handle, put the file tang into the hole in the handle. Then tap the butt end of the handle on the bench. This drives the file firmly into the handle. Never try to hammer the file into the handle. The file is brittle, and hammering could shatter it.

Now here is a tip you can use in the shop: Sometimes you must save and reuse a bolt that has battered threads. Note how the threads are flattened, or pushed down, so that a nut will not turn on the bolt. Clamp the bolt head in a vise, with the battered threads up. Select a 6-inch [152-mm] triangular file. With one edge, file into the root between two battered teeth. Use a rounding stroke to follow the circumference of the bolt. Continue to file until all the material that was battered down is removed and the nut can be turned onto the bolt. If the job is well done, the nut should go on and turn easily.

○ 6-5 TAPS Taps are used to cut screw threads in holes in metals and plastics. A tap looks somewhat like a screw, but the tap has a square end to fit into a tap wrench. Flutes, or grooves, run the length of the threads. They allow chips cut from the metal to escape so they do not jam the tap threads as shown in Fig. 6-7.

Taps are made in several styles. To tap a hole that has been drilled, the square end of the tap fits into a tap handle like the one shown in Fig. 6-7.

Taps are available in many different sizes. The tap size is the classification of the threads being cut. For example, to tap a hole for a 1/4-20 bolt, you use a tap marked 1/4-20. Most taps have their sizes etched on the shank. Taps are very hard, as they must be to cut threads in metal. Therefore, taps are very brittle. The smaller the diameter of the tap, the easier the tap will break. Be very careful when using taps with a diameter of 1/8 inch [3 mm] or less. These small taps break

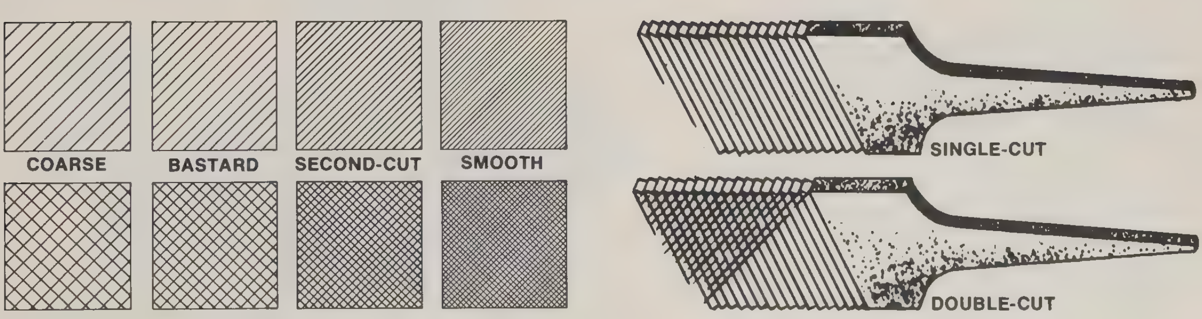


FIG. 6-6 Types of file cuts.

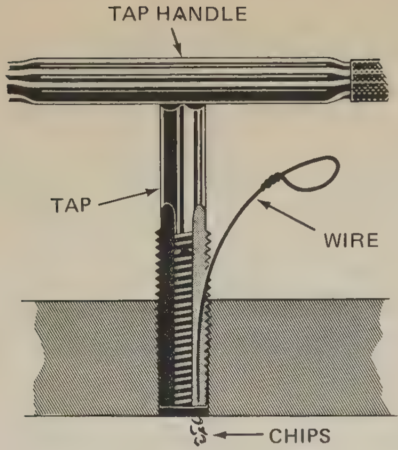


FIG. 6-7 Using a wire to clean metal clips from the flutes of a tap.

easily, and a broken tap can be very difficult to remove. Sometimes a part with a broken tap in it must be replaced with a new part because it is impossible to remove the broken piece of the tap.

To tap a hole that goes completely through a piece of metal, as shown in Fig. 6-7, you use a taper tap. To thread a hole only part way, you use a plug tap. To make threads all the way to the bottom of a hole that is open on only one end, you use a bottoming tap.

To make a tapped hole in a piece of metal, first determine the thread size you need. Then consult a tap drill chart, such as shown in Fig. 6-8. This chart shows you the size of drill required to make the proper hole for the threads. Selection of the tap is based on the size of the hole, the type of thread to be cut, and whether the hole is to be tapped all the way through the work.

○ 6-6 THREAD DIES A die is run over the outside of a rod to make external, or outside, threads. The die is held in a die stock such as shown in Fig. 6-9.

Taps are not adjustable. However, some method must be available to vary threads that are being cut in order to provide a tight or loose fit. Many dies have an adjusting screw. The screw can be set to cut the standard thread depth or to cut slightly oversize or undersize threads. With the adjusting screw, the die can be set to cut 0.001 to 0.003 inch [0.03 to 0.08 mm] under or over the standard size.

Not all dies are alike. Some small dies are not adjustable. Other dies are 12-sided (have 12 points) on the outside. These dies may be turned with a 1-inch socket in tight places where a die stock cannot be used. The adjusting screw on an adjustable round die is used to make a fine adjustment of the depth of thread to be cut. Tightening this screw spreads the die for a slightly shallower cut, resulting in a tighter fit. Another type of die is the round split die. This type of die is used in a die stock which has setscrews. The setscrews are tightened to make a fine adjustment of the thread depth.

Thread size and threads per inch	Drill (see note below table) Size	No.	Thread size and threads per inch	Drill (see note below table) Size	No.
1-64	0.0595	53	10-32	0.1610	20
1-72	0.0595	53	12-24	0.1770	16
2-56	0.0670	82	12-28	0.1800	15
2-64	0.0700	50	1/4-20	0.1990	8
3-48	0.0781	5/64	1/4-24	0.2090	4
3-56	0.0810	46	1/4-32	0.2187	7/32
4-40	0.0890	43	5/16-18	0.2570	F
4-48	0.0935	42	5/16-24	0.2720	I
5-40	0.0995	39	5/16-32	0.2812	9/32
5-44	0.1040	37	3/8-16	0.3125	5/16
6-32	0.1065	36	3/8-24	0.3320	Q
6-40	0.1130	33	3/8-32	0.3437	11/32
8-32	0.1360	29	7/16-20	0.3906	25/64
8-36	0.1360	29	7/16-28	0.4162	13/32
10-24	0.1470	26	1/2-20	0.4531	29/64

NOTE: *Drill sizes are designated in four ways by numbers (Nos. 80 to 1 or from 0.135 to 0.228 in.), by letters (A to Z or from 0.234 to 0.413 in.), by fractions (1/64 to 3½ in.), and by millimeters (in the metric measurement system).*

NOTE: *The drill sizes indicated in the table are based on approximately 75 percent thread depth; that is, the tap will not give a full thread when it is run down into the hole but will give a 75 percent thread. This means that the top 25 percent, or one-fourth of each thread crest is absent. However, the remaining 75 percent is sufficient for most commercial purposes. For special precision applications, a fuller thread may be desirable. The fuller thread increases the thread strength only slightly (perhaps 5 percent) but makes the tapping job much harder; many more taps are broken.*

FIG. 6-8 Table of drills for tapped holes.

There is a shoulder on the inside bore at the top of the die stock so that the chamfered teeth are away from the shoulder. There is a chamfer on one side of the die. The die teeth are cut straight to the back of the die. The chamfered opening is the side that you place on the rod to be threaded.

To thread a rod, brush some tapping compound or soluble oil on the rod. Then carefully start the die

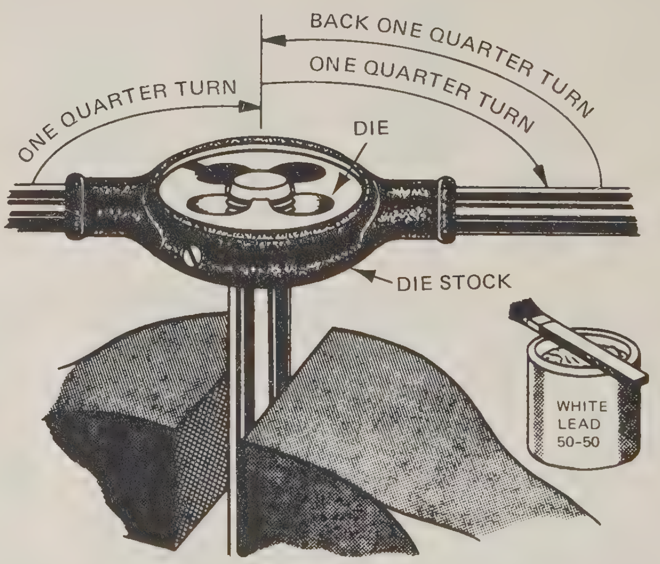


FIG. 6-9 To use a die properly, turn it ahead one-half turn, then back one-quarter turn, while keeping the threads coated with lubricant.

squarely with the work as shown in Fig. 6-9. To start the thread, hold one handle in each hand, and apply downward pressure, while turning the die stock. When you feel the die starting to cut teeth, turn the die stock forward one-half turn and back one-quarter turn. This breaks off the chips and prevents them from jamming the threads. Add lubricant every couple of turns. When you have cut the length of thread desired, remove the rod. Test the threads with a nut of the correct size. It should go on smoothly and evenly and should not have any play or wobble.

○ 6-7 STUD REMOVERS Sometimes a stud or screw will break off. Often this occurs while you are threading a screw into a hole. The screw strikes chips or dirt at the bottom of the hole, and the head twists off. This can happen easily to smaller sizes of screws. The bolt may snap off in two different ways. It may break with a fairly long piece sticking up above the hole, or it may break off flush with the hole. How the broken piece is removed depends on where the screw broke.

To remove a broken screw sticking up above the hole, attach Vise-Grip, or locking, pliers to the protruding part as shown in Fig. 6-10. Then try to turn the broken screw. In most cases, it can be turned out easily.

There are other ways to remove a broken stud or screw. If the break is above the surface, it may be possible to file flats on two sides. Then a wrench can be used to back it out. Or a slot may be cut so that a screwdriver can be used. Light tapping with a hammer on the top and around the sides of a broken screw may help loosen it.

A different procedure is required when the screw breaks off about flush with the hole. You may have to drill out the center of the screw and remove the remainder with a screw extractor. However, the first and easiest way is to try removing the broken screw with a center punch. This technique is shown in Fig. 6-11. Place the point of the punch on the screw, but not at its center. Tap the punch lightly with a hammer to try to back the broken part out of the hole. This method will not work on screws that break because of rust or cross-threading.

If the break is about level with, or below the surface of, the hole, a screw or bolt extractor such as shown in Fig. 6-12 is required. One type, called the Ezy-Out, is tapered and has a coarse spiral thread. Other types of screw extractors have gradually tapering flutes instead of spiral threads. Both work by wedging against the shell of the broken screw after the center of the screw is drilled out. Screw extractors are available in sets, because larger screws require larger screw extractors.

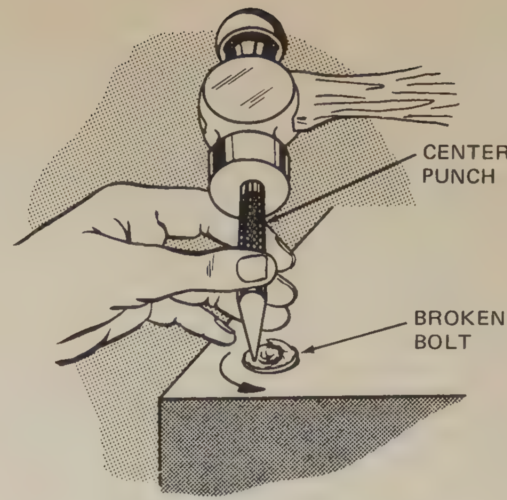


FIG. 6-11 Removing a broken screw with a center punch.

The first step in removing a screw broken off at the surface is to file the broken portion smooth, if possible. Then center-punch the exact center of the screw. Next determine the size of the broken screw you are trying to remove, and select the drill size to use. Following good safety procedures, and wearing eye protection, drill out the center of the screw. If the screw has a fairly large diameter, use a small drill first. Follow this with a larger drill. Try to make a hole nearly as large as the small diameter of the threads. This will leave only a thin shell.

Now insert a screw extractor of the correct size into the hole. Drive the screw extractor into place with a few taps from a hammer. This will cause the edges of the extractor to bite into the sides of the shell. To get the broken piece out, fit the tap handle from your

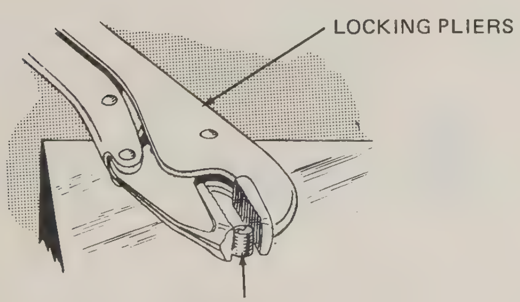


FIG. 6-10 Removing a broken screw with locking pliers.

FIG. 6-12 Using a bolt extractor to remove a broken stud. *(General Motors Corporation)*

tap-and-die set to the extractor. Turn the tap handle, using both hands, to turn out the broken screw. If a tap handle is not available, turn the extractor with a wrench.

When no extractor is available, a diamond-point chisel can be used to remove a broken screw. Drill out the screw as outlined above. Then drive the end of the diamond-point chisel into the hole. Use a wrench to turn the chisel and remove the screw.

Another method of removing a broken screw or stud is to drill out as much of the center of the broken piece as possible. Be careful that the drill does not touch the inside of the threads. Then use a chisel to collapse the remaining shell as shown in Fig. 6-13. Once collapsed, the shell of the screw can usually be worked out easily. Use care to avoid damaging the threads of the tapped hole. After removing the screw, examine the tapped hole. If the threads are damaged, retap them with the proper tap.

○6-8 METAL TUBING CUTTER AND FLARING TOOL Small engines and small-engine powered equipment use copper and steel tubing to carry air or fluid from one part of the engine to other parts. Such a piece of tubing is shown in Fig. 6-14. Any time a section of tubing is replaced, you probably will have to cut, bend, and flare it. Rolls of tubing are available from dealership parts departments and local auto-parts stores. Steel-wire armor wrapping is also available. It is used to cover tubing that is exposed to stone damage.

All fittings on steel lines must be double-flared. Seamless steel tubing can be bent and flared with a tubing cutter and a flaring tool. With the proper tools and a little practice, steel tubing is as easy to work as copper tubing. The proper way to cut tubing is with a tubing cutter. Never use shears or a hacksaw or break the tubing by bending it back and forth. A tubing cutter, shown in Fig. 6-15, is similar in construction and operation to a pipe cutter. A cutting wheel and two rollers are positioned to hold the piece of tubing between them. The rollers are adjustable. They are moved toward or away from the cutting wheel by the adjusting screw.

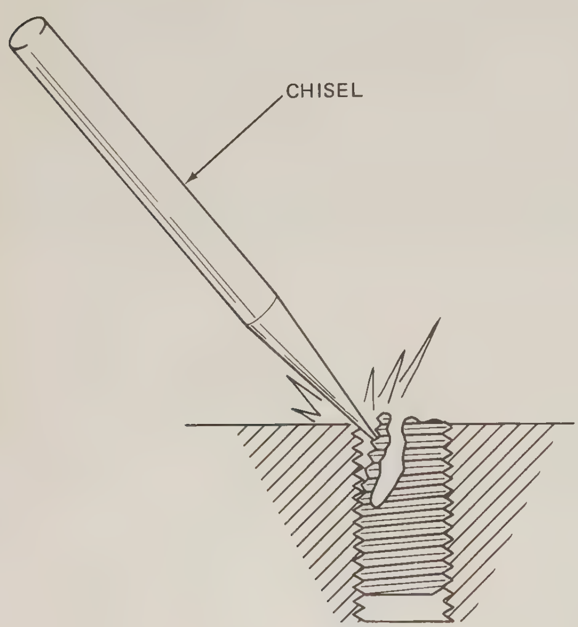


FIG. 6-13 Remove the drilled shell of a broken screw by collapsing it with a chisel. *(Ford Motor Company)*

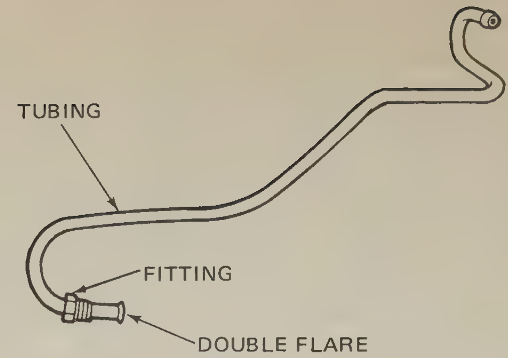


FIG. 6-14 A fuel line, used to carry gasoline from the fuel pump to the carburetor.

The only safe way to bend copper, aluminum, and steel tubing is with a tubing bender. Several different types are available. One type will bend the most commonly used sizes of tubing at angles of up to 180°. This tubing bender has a movable forming block with several tubing channels. Each channel accepts one of the four different sizes of commonly used automotive tubing. For heavy jobs, the bender can be mounted in a vise. In general, you should never try to bend tubing without a tube bender.

Tubing is used to connect the parts of air- or liquid-operated systems. To prevent leakage at the connections, the ends of the tubing are flared. A flare is a widening at the end of the tube. It is shaped like a funnel and held in the connector by a threaded fitting. A flaring tool, such as shown in Fig. 6-16, must be used to flare a tube without cracking it. There are two types of flare: the single flare and the double flare. Most engines and equipment connections require double flares. Single flares are not strong enough and may crack in service. A fitting or flare nut is often used to fasten a flared tube to a flare fitting. If

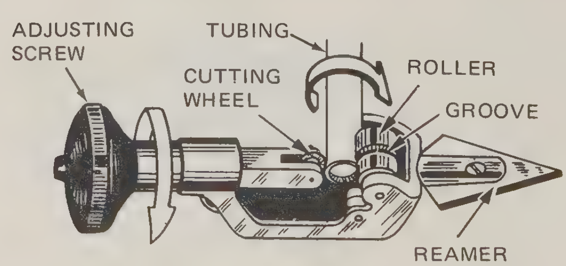


FIG. 6-15 Cutting tubing with a tubing cutter. *(Imperial Brass Manufacturing Company)*

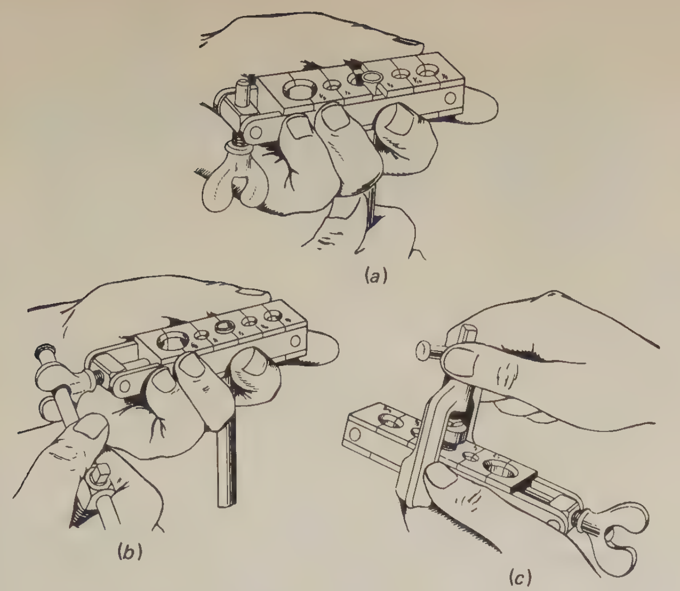


FIG. 6-16 Using a flaring tool to flare the end of a tube. *(Imperial Brass Manufacturing Company)*

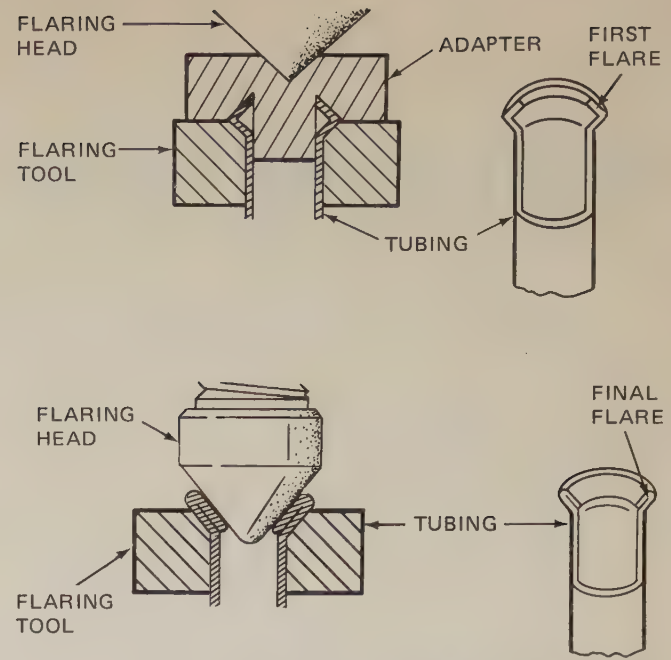


FIG. 6-17 Using an adapter to make the first flare (top). Making the final flare in the double-flare procedure (bottom).

so, the fitting or nut should be placed on the tube before it is flared.

As you can see in Fig. 6-16, the flaring tool has several different sizes of openings. There is one opening for each size of tubing that the tool can flare. If necessary, square the ends of the tubing with a file. Then ream the tubing again to remove any burrs. Make certain that no chips or filings are left in the tube. Loosen the wing nut of the flaring tool until the tubing will fit in the proper opening. Place the tube in the opening, with the end slightly above the tool. Then, holding the tubing in place, tighten the wing nut.

Select the correct size of double-flare adapter from the flaring kit. Place it in the end of the tube that is sticking up above the flaring tool as shown in Fig. 6-17. Then place the yoke flaring head in the recess in the adapter. Tighten the handle of the yoke. Figure 6-17 (top) shows this first step in the double-flaring procedure.

Loosen the yoke, remove the adapter, and note the condition of the flare. It should be as shown at the top of Fig. 6-17. The first flaring operation should leave the end of the tubing bent outward and upward at about a 45° angle.

Place the flaring head directly in the tubing, and tighten the handle as shown in Fig. 6-16. As the flaring head goes down into the tubing, the head will bend down the first flare, making a tight double flare as shown in the lower part of Fig. 6-17. Remove the flaring head and yoke, and inspect the flare. If it is correctly made and without cracks, be sure all fittings or nuts are in place. Then flare the other end of the tube.

REVIEW QUESTIONS

1. Describe the proper way to use a chisel.
2. Explain how to use a hacksaw.
3. What is a tap? What is a die? Describe their uses.
4. Explain how to remove a broken stud.
5. Describe how to cut and flare tubing.
6. Explain how to sharpen a chisel.

SELF PROJECTS

1. Study the catalog of a hand-tool manufacturer, and make a list of hand tools you would like to own.
2. Make a list of the special tools for small engines that you find in the catalog. Explain what they are used for.

Chapter 7

Measuring Tools

After studying this chapter, you should be able to:

1. **Describe the various measuring tools and explain how each is used**
2. **Explain how to read the USCS micrometer and how to convert the readings into metric measurements**
3. **Read the metric micrometer**
4. **Demonstrate the use of the vernier caliper**

○ 7-1 IMPORTANCE OF MAKING CORRECT MEASUREMENTS All the parts that go into engines and machines have exact measurements (length, width, diameter, thickness). Many of the parts have extremely close fits, and so some dimensions must be accurate to within one-thousandth of an inch [0.03 mm]. The service technician must be constantly measuring these dimensions to make sure that the different parts will fit together correctly. If the measurements are not made accurately, the parts may not fit together correctly and a failure will occur.

Many measurements are made in inches or fractions of an inch. However, as the United States begins to use the metric system, the meter and its divisions will become familiar to the mechanic. We will study the metric system of measurements first. Then we will look at some of the most frequently used measuring tools.

○ 7-2 BASIC MEASURING SYSTEMS There are two basic measuring systems that we use in working with small engines, motorcycles, and automobiles. The first one is the inch-foot-mile measurement. This is the United States Customary System. It includes liquid measurements of pints, quarts, and gallons, and weight measurements of ounces, pounds, and tons. The second system is called the metric system. In the metric system, everything is measured by tens, just as in our money system (10 pennies make a dime, 10 dimes make a dollar). Likewise, the metric system starts out with a millimeter, which is a very small distance of about 0.0394 inch. Ten millimeters (abbreviated mm) equals one centimeter (abbreviated cm). One inch is equal to 25.4 mm. It is important for you to know about the metric system because some small engines are built to metric measurements. When you work on these engines, you will have to use tools made to metric measurements. So let us find out about the metric system.

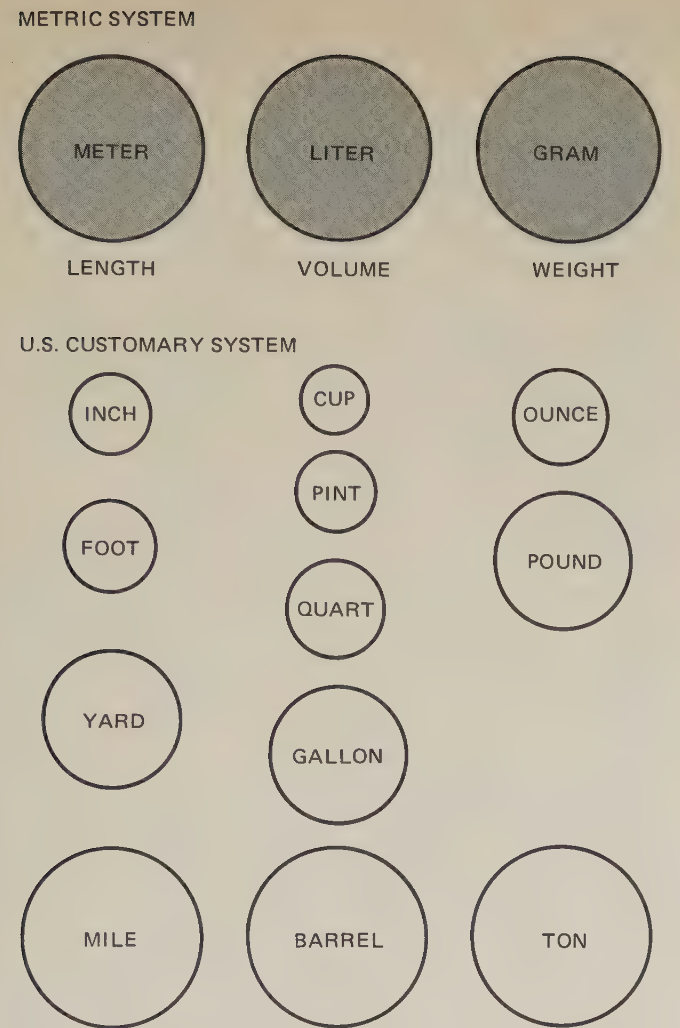


FIG. 7-1 Three metric units replace many different U.S. Customary System units.

○ 7-3 COMPARING THE METRIC AND U.S. CUSTOMARY SYSTEM First, let us look at the inch-foot-mile and pint-quart-gallon system. This is the United States Customary System (USCS). The measurements in the system include the following:

Length

12 inches = 1 foot
3 feet = 1 yard
5280 feet = 1 mile

Liquids

16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon

Weight

16 ounces = 1 pound
2000 pounds = 1 ton

Length

1 millimeter = 0.039 inch
10 millimeters = 1 centimeter (0.394 inch)
100 centimeters = 1 meter (39.37 inches, or a little more than 1 yard)
1,000 millimeters = 1 meter
1,000 meters = 1 kilometer (0.62 mile)

Volume (liquid)

1,000 milliliters = 1 liter (1.057 quarts)

Weight

1,000 milligrams = 1 gram (0.035 ounce, or the approximate weight of a paper clip)
1,000 grams = 1 kilogram (2.2 pounds)
1,000,000 milligrams = 1 kilogram
1,000 kilograms = 1 metric ton

FIG. 7-2 Some basic metric measurements.

Looking at these figures, you could become a little confused. Our system did not grow logically.

The metric system, however, is more logical (Fig. 7-1). It is based on the decimal system, on multiples of 10. For example, 1 meter (m) (which is 39.37 inches) is 10 decimeters (dm), or 100 centimeters, or 1000 millimeters. Volume, in the metric system, is measured in liters (L). One liter equals 1.057 quarts. In other words, a liter is a little larger than a quart.

As you can see in Fig. 7-1, the metric system's three units of measure replace many different units used in the U.S. Customary System. Weight is measured in grams (g), length in meters, and volume in liters. The units of money are the same in both systems. Also, time is measured in the same units of hours, minutes, and seconds used in the U.S. Customary System. Now, let us look more closely at some basic metric measurements shown in Fig. 7-2.

You have probably noticed that the names of metric units sometimes include prefixes ("milli-," "centi-," "kilo-," etc.) as in "milliliter," "centimeter," and "kilogram." These prefixes indicate multiples or submultiples of the units. The most commonly used prefixes and the multiplication factors they indicate are given in Fig. 7-3.

The term "kilometer" means 1000 meters. A centimeter is $^{1}/_{100}$ of a meter, and a millimeter is $^{1}/_{1000}$ of a meter. The conversion table shown in Fig. 7-4 gives you the metric measurements that you need to work

Prefix	Multiplication factor
kilo	1000 (one thousand)
centi	0.01 (one hundredth)
milli	0.001 (one thousandth)

FIG. 7-3 Commonly used prefixes in the metric system and the multiplication factors they indicate.

LENGTH

1 in. (inch)	= 25.4 mm (millimeters)	= 0.0254 m (meter)
1 cm (centimeter)	= 0.390 in.	= 0.03281 ft (foot)
1 mm (millimeter)	= 0.039 in.	= 0.003281 ft
1 ft	= 304.8 mm	= 0.3048 m
1 mi (mile)	= 1.609 km (kilometers)	= 1,609 m
1 km	= 0.62 mi	= 3,281 ft

VOLUME/CAPACITY

1 cu in. (cubic inch)	= 16.39 cc (cubic centimeters)	= 0.01639 L (liter)
1 cc	= 0.061 cu in.	= 1 ml (milliliter)
1 L	= 61.2 cu in.	= 1,000 cc
1 gal (gallon)	= 4 qt	= 3.7854 L
1 fl. oz. (fluid ounce)	= 29.57 cc	= 29.57 ml

WEIGHT

1 kg (kilogram)	= 2.2 lb (pounds)	= 35.2 oz (ounces)
1 lb	= 0.454 kg	= 16 oz
1 oz	= 0.0625 lb	= 28.35 g

TORQUE

1 lb-ft (pound-foot)	= 12 lb-in. (pound-inch)	= 0.138 kgm (kilogram-meter)
1 kgm	= 7.233 lb-ft	= 86.796 lb-in.

Here are the metric measurements, taken from the complete Metric System Table, that you will work with most often.

LENGTH

1 km	= 1,000 m	= 100,000 cm
1 m	= 100 cm	= 1,000 mm (millimeters)

VOLUME/CAPACITY

1 kl (kiloliter)	= 1,000 L	= 100,000 cl (centiliters)
1 L	= 1,000 cc	= 1,000 ml (milliliters)

WEIGHT

1 kg (kilogram)	= 1,000 g (gram)	= 100,000 cg (centigrams)

FIG. 7-4 Conversion table: The U.S. Customary System versus the metric system.

on imports, along with their USCS equivalents. With this table, you can convert USCS measurements to metric measurements, and vice versa.

Now study Fig. 7-5 to familiarize yourself with the difference between metric and standard sizes of sockets.

○ 7-4 RULES The common rule, or steel scale, such as shown in Fig. 7-6, is marked off in inches and fractions of an inch. Sometimes these markings are as small as 1/64 inch. Other rules or steel scales are marked with both inches and centimeters. This is the type shown in Fig. 7-6. The top markings are the centimeter scale. Rules are also made with only metric markings.

Examine the markings on the illustrated steel rule, which is also called a scale (Fig. 7-6). Note that the longest line between the inch marks is the 1/2-inch mark. Shorter lines are used for the 1/4-inch marks. Still shorter lines are used for the 1/8- and 1/16-inch marks.

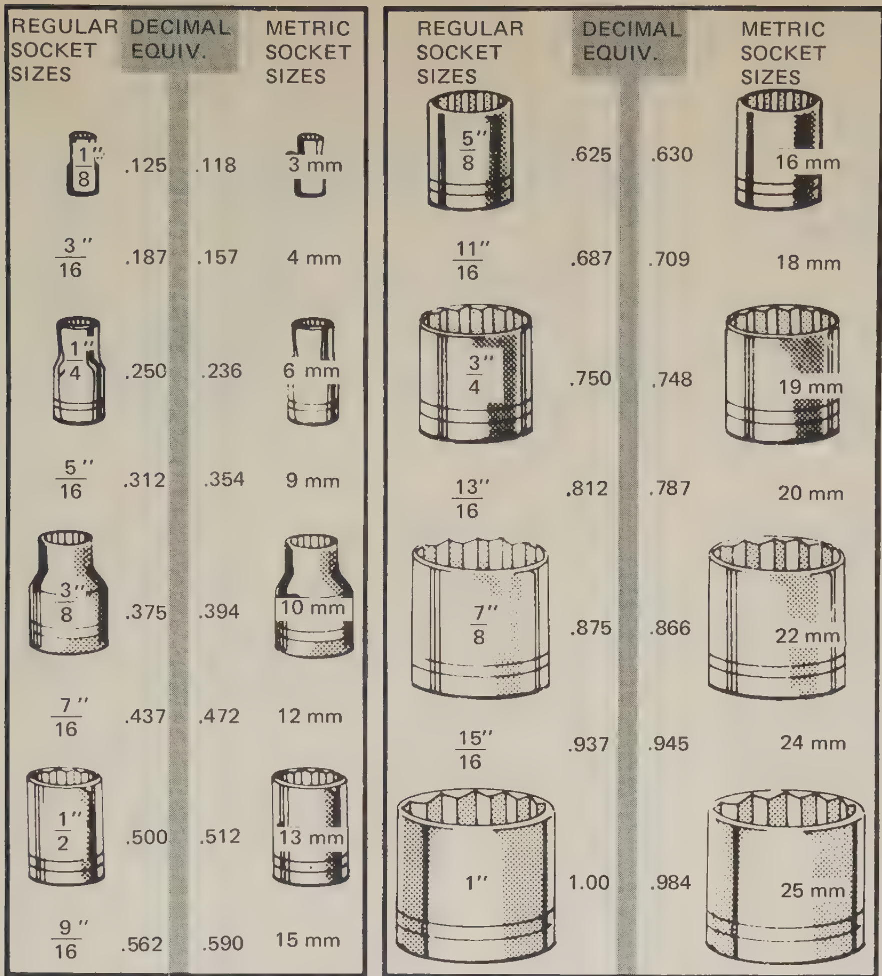


FIG. 7-5 Comparison of metric and standard sizes sockets in the U.S. Customary System. *(Dana Corporation)*

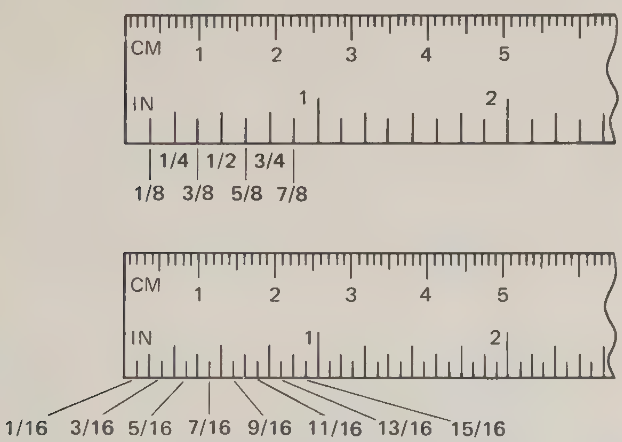


FIG. 7-6 Rule, or steel scale, marked in inches (U.S. Customary System) and centimeters (metric system).

1/64	.0156	17/64	.2656	33/64	.5156	49/64	.7656
1/32	.0312	9/32	.2812	17/32	.5312	25/32	.7812
3/64	.0468	19/64	.2969	35/64	.5469	51/64	.7969
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.0781	21/64	.3281	37/64	.5781	53/64	.8281
3/32	.0937	11/32	.3437	19/32	.5937	27/32	.8437
7/64	.1094	23/64	.3594	39/64	.6094	55/64	.8594
1/8	.125	3/8	.375	5/8	.625	7/8	.875
9/64	.1406	25/64	.3906	41/64	.6406	57/64	.8906
5/32	.1562	13/32	.4062	21/32	.6562	29/32	.9062
11/64	.1719	27/64	.4219	43/64	.6719	59/64	.9219
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.2031	29/64	.4531	45/64	.7031	61/64	.9531
7/32	.2187	15/32	.4687	23/32	.7187	31/32	.9687
15/64	.2344	31/64	.4844	47/64	.7344	63/64	.9843
1/4	.25	1/2	.5	3/4	.75	1	1.0

FIG. 7-7 Table of decimal equivalents.

Another type of rule has one edge divided into decimal fractions of an inch. The inches are divided into 50 equal parts so that a measurement of 0.020 (twenty-thousandths) inch can be read directly from the rule. Refer to the decimal-equivalent chart shown in Fig. 7-7. Note that this measurement is slightly larger than 1/64 inch.

○ 7-5 FEELER GAUGES Feeler gauges are strips or blades of hardened steel or other metal, ground or rolled with extreme accuracy to the proper thickness. This is the reason feeler gauges are sometimes called thickness gauges. They are generally supplied in sets, such as shown in Fig. 7-8. Each blade is marked with its thickness in thousandths of an inch, hun-

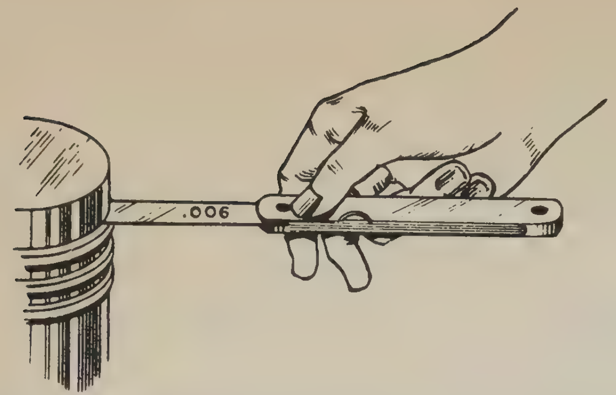


FIG. 7-8 Using a feeler gauge to check the side clearance of the piston ring in the ring groove.

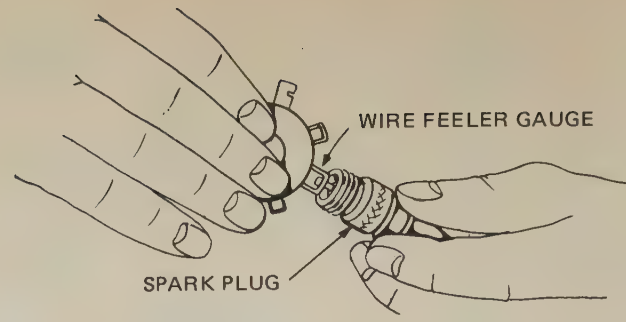


FIG. 7-11 Using a wire feeler gauge to check spark-plug gap. *(Briggs & Stratton Corporation)*

dredths of a millimeter, or both. Figure 7-8 shows a feeler gauge being used to check piston-ring clearance.

Some feeler gauges have two steps, or thicknesses, as shown in Fig. 7-9. These are stepped feeler gauges. The tip of the blade of a stepped feeler gauge is thinner than the rest of the blade. The blade marked 4–6 in Fig. 7-9 is 0.004 inch [0.10 mm] thick at the tip. The thicker portion that starts about 1/2 inch back from the end of the blade is 0.006 inch [0.15 mm].

Stepped feeler gauges are handy on certain jobs where the specifications might, for example, call for a clearance of 0.005 inch [0.13 mm]. By using the 0.004- to 0.006-inch [0.10- to 0.15-mm] gauge, an adjustment can be made so that the 0.004-inch [0.10-mm] portion will fit and the 0.006-inch [0.015-mm] portion will not fit. For this reason, stepped feeler gauges are often called *go, no-go* gauges.

Wire feeler gauges, like the set shown in Fig. 7-10, are similar to the flat feeler gauges, except that they

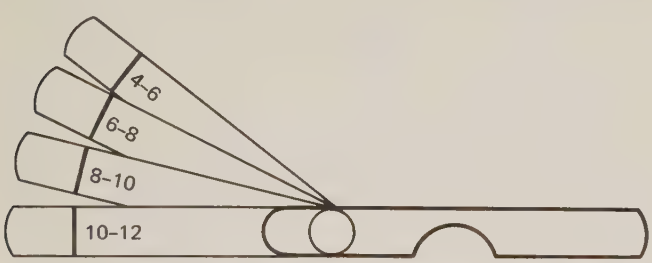


FIG. 7-9 A set of stepped feeler gauges. These are also called go, no-go feeler gauges.

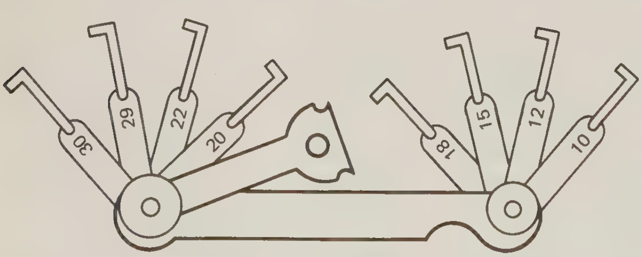


FIG. 7-10 Set of wire feeler gauges.

are made of carefully calibrated steel wire of the proper thickness. They are useful in checking spark-plug gaps and similar dimensions, as shown in Fig. 7-11. Metric wire feeler gauges are also available. When specifications are given in the metric system and you do not have metric gauges, you can convert the measurements by using metric conversion charts.

Feeler gauges are made in many shapes and sizes. Some feeler gauges, or blades, are straight, as in Figs. 7-8 and 7-9. Other feeler gauges are bent at an angle, as in Figs. 7-10 and 7-11. A feeler gauge set usually consists of several blades which often range in thickness from 0.0015 to 0.040 inch [0.037 to 1.02 mm]. Sometimes you might need to measure a space that is a size for which your set does not have a blade. Should this happen, you can make up the size gauge you need by combining blades of various thicknesses from the set. The total thickness of all the blades used to fill the space is the measurement between the surfaces.

Most feeler gauges are made of steel. However, sometimes a mechanic needs a nonmagnetic feeler gauge. Brass feeler gauges are available for work around permanent magnets, such as measuring the air gap in an electronic distributor or a magneto. A permanent magnet will attract the steel gauge and prevent an accurate measurement.

○7-6 MICROMETERS Measurements made with a steel scale are usually not accurate enough for engine service and repair work. In such work, measurements must be taken in much finer detail than 1/64 inch [0.397 m]. For these measurements, more precise instruments are used, such as the micrometer, the dial indicator, and the vernier caliper.

A typical micrometer is shown in Fig. 7-12. The micrometer measures much more accurately than a steel rule. In addition, the measurements can be read directly from the micrometer itself. Instead of reading in fractions of an inch like many rulers, the micrometer measures in tenths, hundredths, thousandths, and

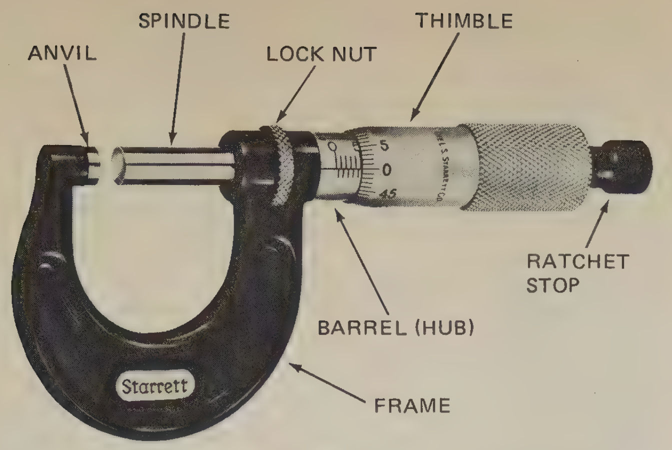


FIG. 7-12 Outside micrometer. *(The L. S. Starrett Company)*

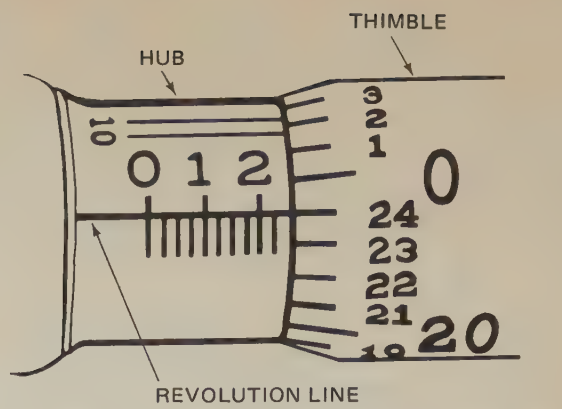


FIG. 7-14 Hub and thimble markings on a micrometer.

sometimes ten-thousandths of an inch. It uses the decimal system.

In the shop, the micrometer is usually called a *mike*, and measuring something with the mike is called *miking*. To use the micrometer to mike the diameter of a round shaft or stock, it is held as shown in Fig. 7-13.

Examine Fig. 7-12. Identify the anvil, frame, spindle, hub, and thimble of the outside micrometer. When you turn the thimble counterclockwise, the spindle moves away from the anvil, uncovering the markings on the hub and thimble. Note that the hub, or barrel, is marked off in uniform spacings of 0.025 (twenty-five–thousandths) inch each (Fig. 7-14). The circumference of the thimble is marked off into 25 graduations. Each graduation represents 0.001 (one-thousandth) inch.

To make a measurement with a micrometer, the thimble is turned until the piece being measured is a light-drag fit between the anvil and the end of the spindle. Then the measurement is read off the barrel and thimble. The barrel markings each indicate 0.025 inch. Four of them make 0.1 inch. If three of the figures are visible, as shown at the top of Fig. 7-15, then the thimble will have uncovered 12 markings and the measurement will be at least 0.300 inch.

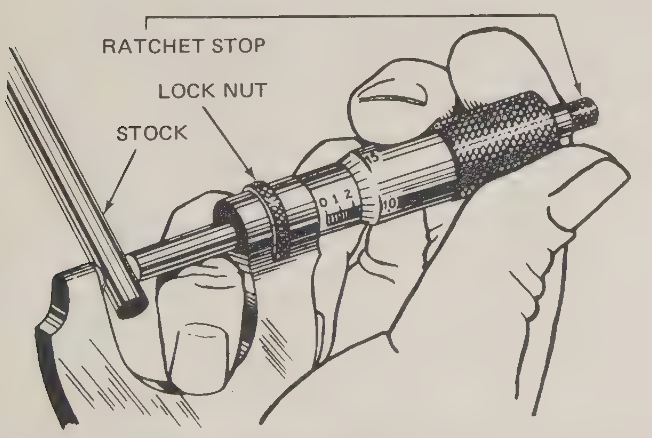


FIG. 7-13 Using an outside micrometer to measure the diameter of a rod.

Notice we said "at least." Noting the figures on the barrel is only the first step in reading the measurement. The second step is to notice exactly where the markings on the thimble stand with regard to the line on the barrel.

At the top in Fig. 7-15, for example, the thimble has been turned so that marking-number 4 on it lines up with the barrel line. This means that the thimble has been turned 0.004 inch past the 0.300-inch mark. The actual measurement being shown at the top is 0.304 inch (0.300 plus 0.004).

Now look at the middle and the bottom of Fig. 7-15. In the middle, the thimble has been turned just one thimble marking past the ninth barrel marking. The barrel markings indicate 0.225 inch. The single thimble marking, indicating 0.001 inch, must be added to give an actual measurement of 0.226 inch. To get a reading on the mike, first note how many barrel markings have been exposed as the thimble is backed off. Each barrel marking represents 0.025 inch. Then notice the thimble marking aligned with the barrel line. Each thimble marking represents 0.001 inch. Add the two to get the total.

Now notice the bottom measurement in Fig. 7-15. Here the thimble has been turned to uncover only eight barrel markings, and so the reading is 0.200 inch. But the thimble has been turned until it is marking 24 lines with the barrel line. This figure is 0.024 inch, and the total measurement is 0.224 inch (0.200 plus 0.024).

The metric micrometer, shown in Fig. 7-16, reads in millimeters and hundredths of a millimeter (0.01 mm). The barrel is marked off in millimeters above the line and half millimeters (0.50 mm) below the line. The thimble is divided into divisions of 0.01 mm. To read the measurement shown on the micrometer in Fig. 7-16, add the reading on the barrel, 11 mm, to the reading on the thimble, 0.45 mm. The total measurement is 11.45 mm. Reading a metric micrometer is probably easier than reading a mike marked in inches.

The micrometer has very precisely cut screw

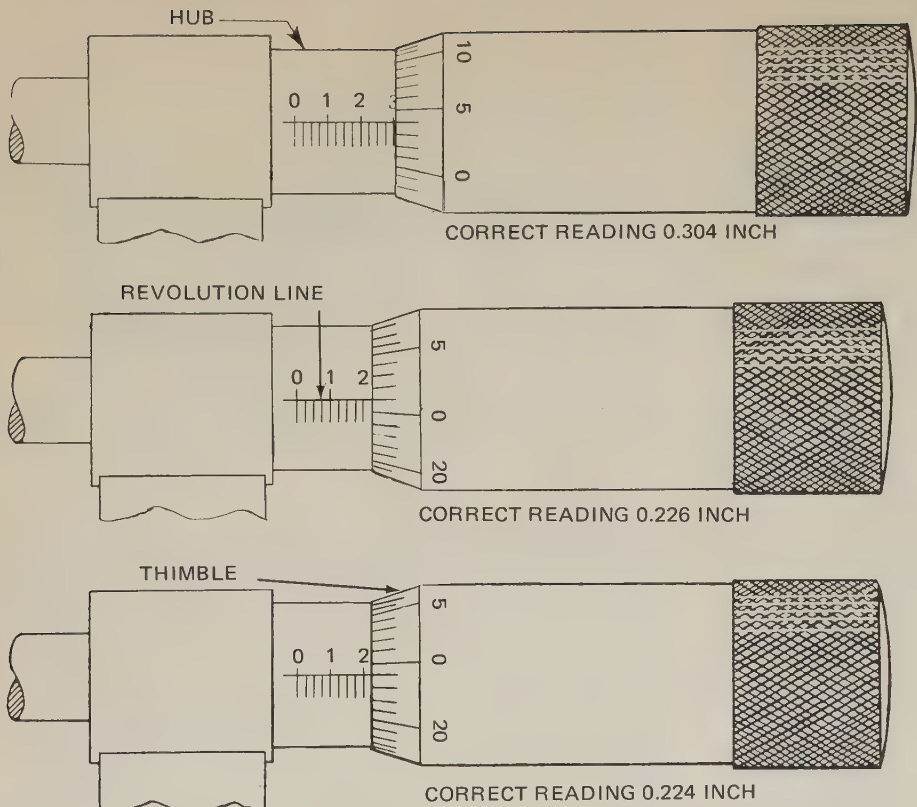


FIG. 7-15 Reading a micrometer.

threads in it, and rough treatment will ruin it. The micrometer should not be thrown about carelessly on the workbench. It should be kept in a special drawer or in a case where it is protected from dirt and from damage by other tools that might be dropped on top of it. It should be wiped clean after every use. Never clamp the micrometer on the piece being measured. The thimble should be tightened only enough to cause the micrometer to drag slightly as it slides over the piece. Clamping will distort the threads and frame and could ruin the micrometer.

Never try to measure a metal part in a lathe while the part is revolving. The micrometer might tighten on the piece and be torn out of your hand. This could

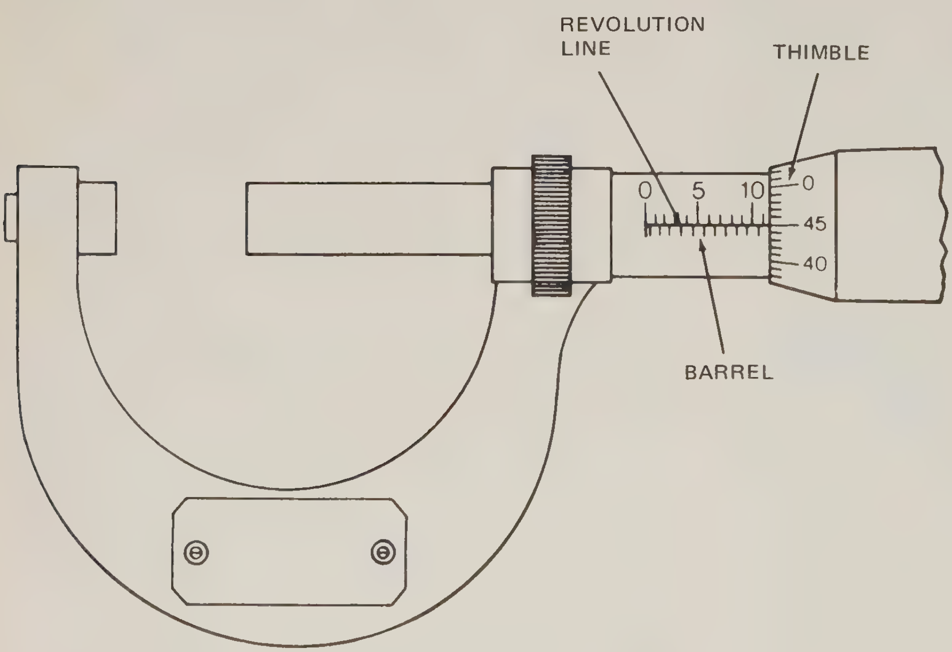


FIG. 7-16 Simplified metric micrometer *(Volkswagen of America, Inc.)*

not only ruin the work and the micrometer but also injure you.

Many variations of the micrometer are used in shopwork. For example, there are inside micrometers for measuring hole diameters like the one shown in Fig. 7-17. In addition, much of the precision power machinery in the shop has micrometer adjustments. Such tools as cylinder honing or boring equipment, lathes, and grinders have micrometer adjustments so that the machining operations can be carefully controlled.

Inside micrometers are used to measure hole diameters, such as the diameter, or bore, of an engine cylinder. Extension rods of various lengths, such as the one shown in Fig. 7-17, can be attached so the mike will measure large diameters. The markings on the hub and thimble correspond to those on the hub and thimble of the outside micrometer. By using the inside micrometer and extension rods, cylinder diameters from $1^1/_2$ inches to several inches can be measured by changing the extension rod.

When assembling an inside micrometer to the length that you need by inserting an extension in the micrometer, be sure that the extension seats properly. There is a shoulder on the rod that must seat in order for the inside micrometer to provide a correct reading.

Figure 7-17 shows an inside micrometer being used to measure the diameter, or bore, of an engine cylinder. To measure a cylinder bore, first turn the thimble clockwise until the overall length of the assembled micrometer is less than the diameter of the cylinder bore. With one hand, hold the head end of the micrometer squarely against the cylinder wall, as shown in Fig. 7-17. Then, with your other hand, turn the thimble to extend the length of the micrometer as you feel for the maximum diameter by moving the rod end slightly from left to right and up and down. When no left-to-right movement of the rod end is possible and a light drag is felt as you move the rod end up and down, take the reading.

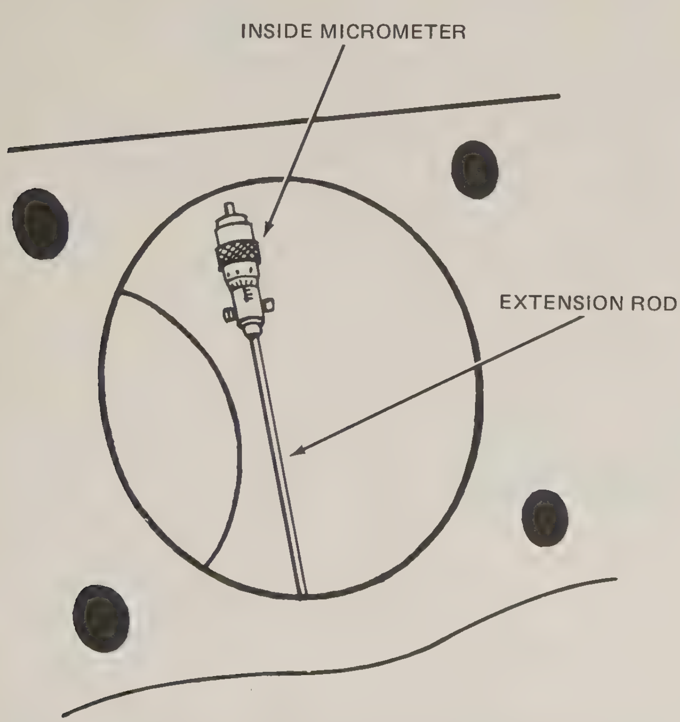


FIG. 7-17 Using an inside micrometer to measure the bore of a cylinder.

○ 7-7 DIAL INDICATOR

The dial indicator is a gauge that uses a dial face and a needle to register measurements. A typical dial indicator is shown in Fig. 7-18. The dial indicator has a movable contact arm. When the arm is moved, the needle rotates on the dial face to show movements in thousandths of an inch.

The dial indicator is used to measure end play in shafts or gears, movement of contact points, runout of disk brake rotors, and so on. Figure 7-19 shows a dial indicator being used to measure the bore, or diameter, of a cylinder. As the dial indicator is moved up and down, any difference in the diameter will cause the needle to move. Differences in the cylinder diameter at the various points indicate cylinder wear. These special dial indicators for measuring cylinder wear also are called cylinder bore gauges.

There are two scales on some dial indicators. In the U.S. Customary System, the outer scale is usually marked in measurements of $^1/_{1000}$ inch (0.001 inch). If an inner scale is used, it frequently records or counts the number of revolutions made by the large indicator

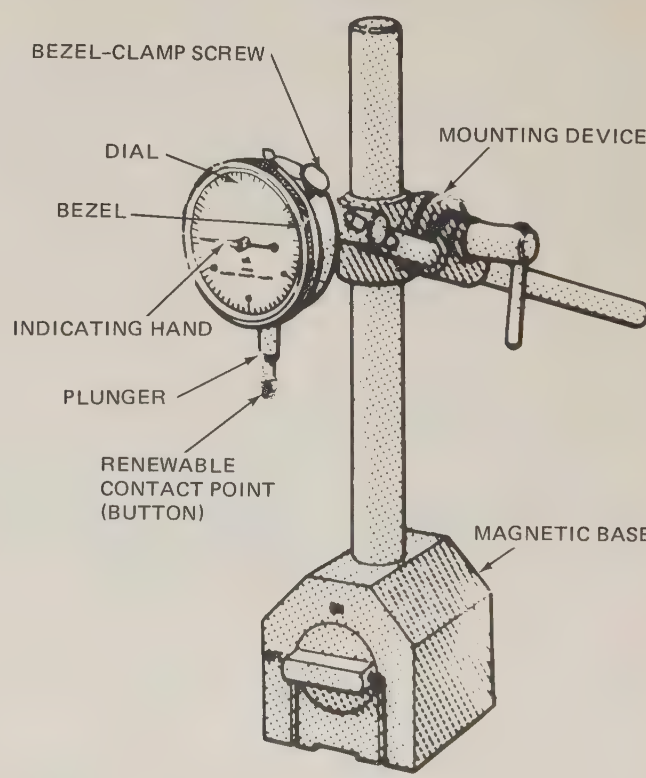


FIG. 7-18 A dial indicator. *(Ford Motor Company)*

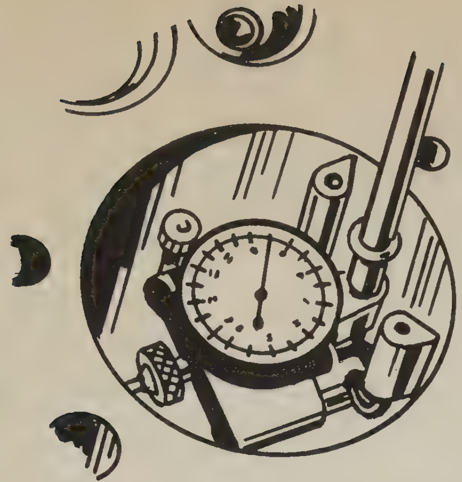


FIG. 7-19 Using a cylinder bore gauge to measure the diameter of a cylinder bore.

needle. On the metric dial indicator, shown in Fig. 7-20, the outer scale is divided into 100 divisions, each division representing $^1/_{100}$ mm (0.01 mm). The inner scale is divided into 10 divisions. Each division is 1 mm, and so every complete revolution of the outer scale represents 1 mm.

Now let us read the measurement shown on the dial indicator in Fig. 7-20. The needle on the inner scale has passed 4 but has not quite reached 5, making a reading of 4 mm. To find out how much more than 4 the complete measurement totals, add the reading on the outer dial. The dial on the outer scale determines the fractional ($^1/_{100}$ mm) reading. In Fig. 7-20, the outer needle is pointing to 98, which is read and written as 0.98. Added together, the total reading is 4.98 mm.

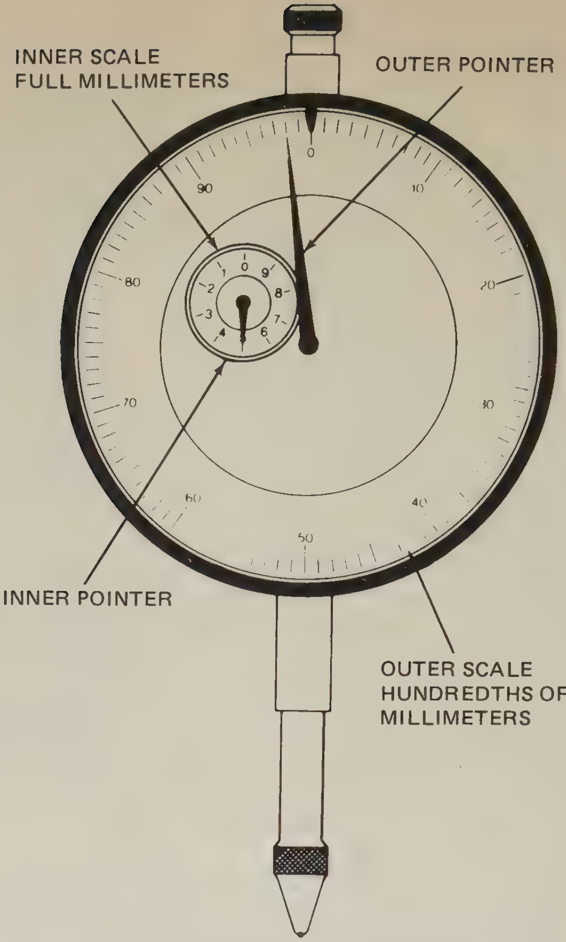


FIG. 7-20 A metric dial indicator. *(Volkswagen of America, Inc.)*

○ 7-8 VERNIER CALIPER In 1631, Pierre Vernier, a French mathematician, invented an accurate, direct-reading scale for use in making linear measurements. When Vernier's scale was combined with an ordinary caliper, the result was a measuring instrument called a vernier caliper. Basically, the vernier caliper is made of two graduated steel rules, such as shown in Fig. 7-21. One rule is fixed and is called the fixed rule or frame. To one end of the frame is attached the fixed jaw. The second rule is movable and slides along the frame. One end of the sliding rule

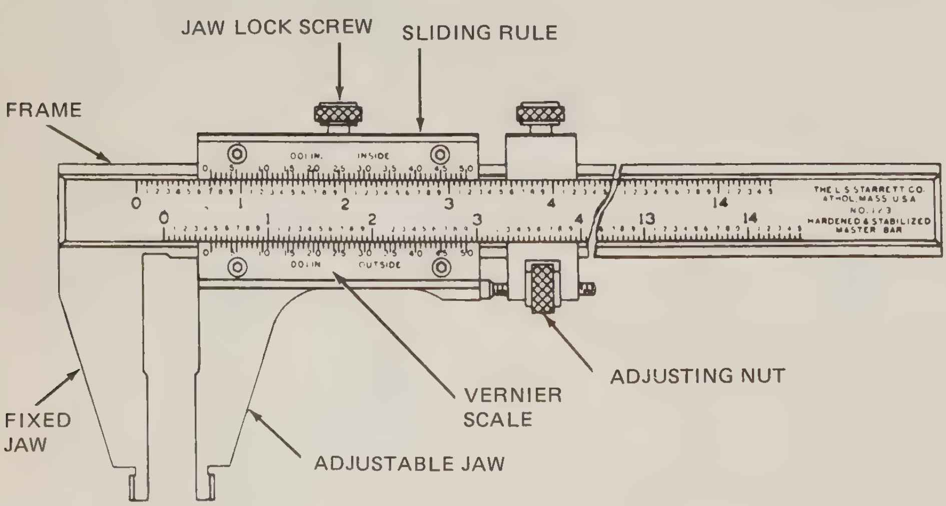


FIG. 7-21 A vernier caliper. *(The L. S. Starrett Company)*

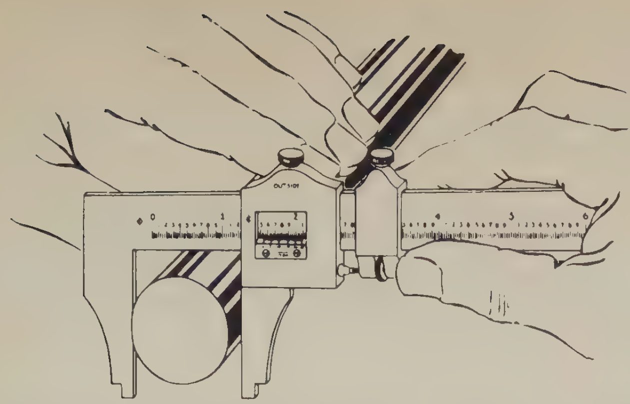


FIG. 7-22 Using the vernier caliper to measure an outside diameter.

has the other measuring jaw attached. This jaw is called the adjustable, or sliding, jaw.

To measure an outside diameter with a vernier caliper, place the object snugly between the jaws of the caliper, as in Fig. 7-22. The number of inches is read off the fixed scale on the frame. To this, add the number of tenths that are seen between the last inch reading and the zero on the vernier scale. Then add the number of 0.025-inch marks seen between the last tenth reading and the zero on the vernier scale. Finally, read the number of lines from zero on the reverse scale to the point where the line on the vernier scale coincides exactly with a line on the fixed scale. Each of these lines represents $^1/_{1000}$ inch (0.001 inch).

Some vernier calipers have slightly different scales on one side to be used for reading inside diameters. Other vernier calipers have different zero marks to be used when reading inside diameters.

Figure 7-23 shows a simplified metric vernier caliper that can be used for practice. On this caliper, the fixed scale is divided into 1-mm sections. The movable vernier scale is divided into 10 lines each representing $^1/_{10}$ mm (0.10 mm). To read the metric vernier caliper, count the number of millimeters on the fixed scale that precede the vernier scale zero. Then look at the vernier scale until a line is located that coincides exactly with a line on the fixed scale. Count each line on the vernier scale from zero to the point where the two lines coincide. Since each line is 0.10 mm, be sure to count by tens. This is the decimal portion of the reading, which must be added to the first reading to obtain the complete measurement.

○ 7-9 SMALL-HOLE GAUGES For measuring small holes or slots that telescope gauges cannot fit into, small-hole gauges can be used. These gauges are available in sets of four or more and will measure distances from about $^1/_8$ to $^1/_2$ inch [3.2 to 12.7 mm]. Figure 7-24 shows a small-hole gauge. It consists of a small split ball mounted on the end of a handle.

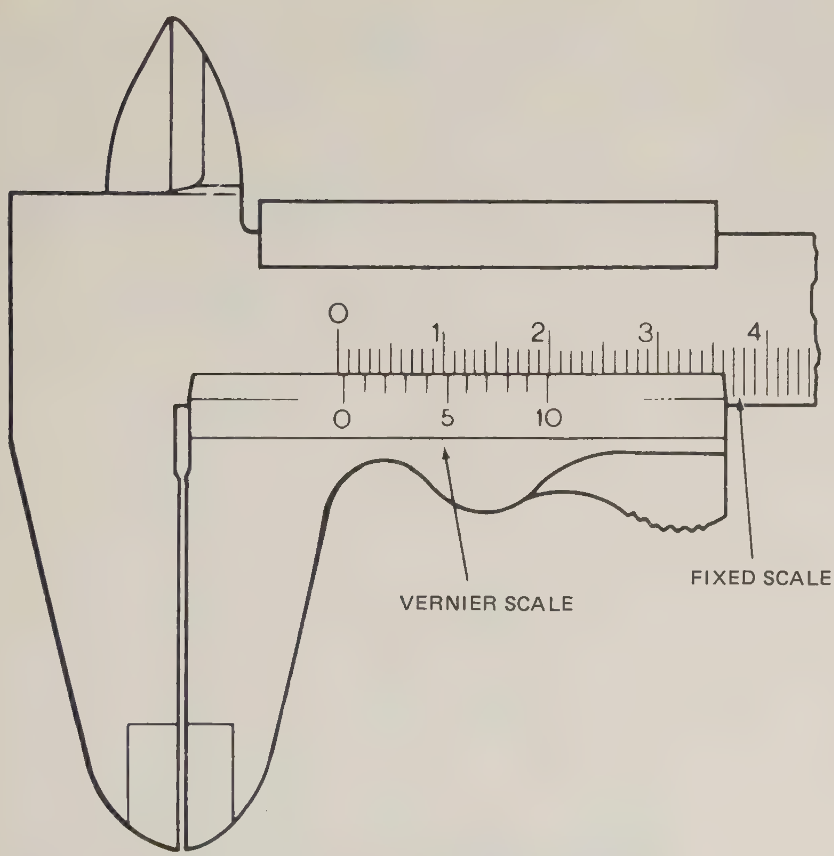


FIG. 7-23 A simplified metric vernier caliper. *(Volkswagen of America, Inc.)*

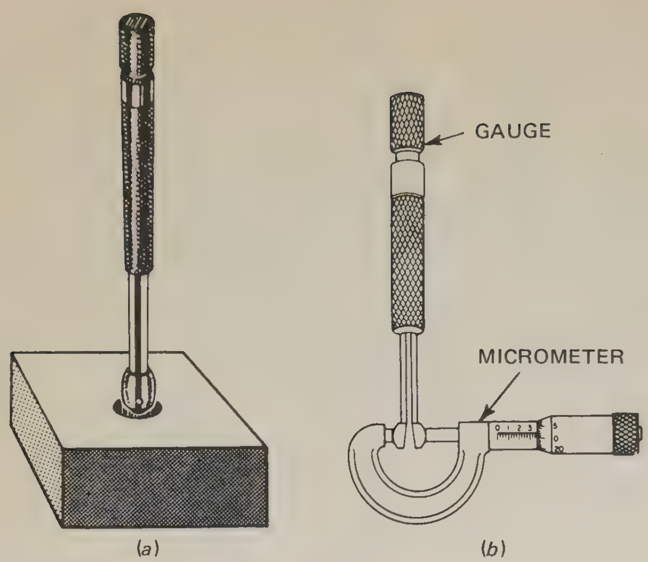


FIG. 7-24 Using a small-hole gauge to measure the size of a hole. (a) Gauge is adjusted to enter hole. (b) Measuring the small-hole gauge with a micrometer to determine size of hole.

When the knurled knob at the top of the handle is turned, the split ball expands. Proper feel is obtained when you can feel a slight drag of the ball end against the sides of the hole. Then remove the gauge from the hole, and measure the size of the ball end with a micrometer. The reading on the micrometer gives you the diameter of the hole. Note the narrow shank that has the split-ball ends attached. The shank is not as wide as the ball ends. This permits the small-hole gauge to extend into a hole or small bore to measure the diameter some distance from the open end.

○7-10 TELESCOPE GAUGES Telescope gauges are used for measuring the diameter of holes up to about 6 inches [152.4 mm] in diameter. A typical telescope gauge is shown in Fig. 7-25. A telescope gauge is a T-shaped measuring instrument that uses the shaft of the T as a handle and uses the cross arm for measuring. To use the telescope gauge, loosen the knurled nut at the end of the gauge handle. Compress the arms with your hand into a size slightly smaller than the cylinder to be measured. Tighten the nut to lock the arms in position.

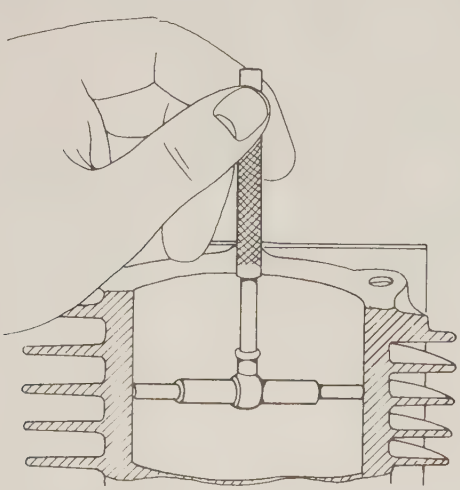


FIG. 7-25 Using a telescoping gauge to measure the diameter of a cylinder bore.

Insert the gauge into the cylinder, as shown in Figure 7-25. Loosen the nut. A light spring inside the arms will push the adjustable end out so that the gauge will adjust to fit the cylinder. Make sure the telescoping end is at right angles to the cylinder wall. Then tighten the nut and withdraw the gauge. To find the diameter of the cylinder, measure the telescope gauge setting with a micrometer.

REVIEW QUESTIONS

1. What is a feeler gauge? Explain how to use it.
2. What is a stepped feeler gauge? Explain how to use it.
3. What is a vernier caliper? Explain how to use it.
4. Explain how to use a micrometer.
5. Explain how to use the decimal-equivalent table.
6. Explain how to use an inside micrometer.
7. Explain how to use a dial indicator and outside micrometer to measure the diameter of a cylinder bore.
8. Explain how the United States Customary System and the metric system differ.
9. Study the conversion table until you understand how to convert inches to millimeters, millimeters to inches, miles to kilometers, gallons to liters, and so on. Then make the following conversions:

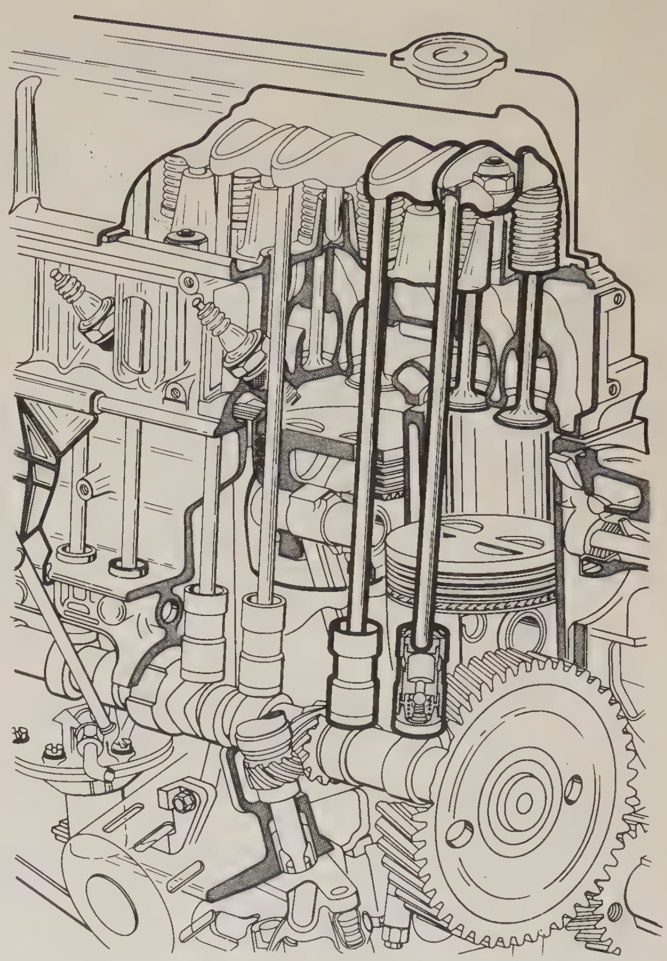
   1 inch = _____ millimeter(s)
   1 millimeter = _____ inch(es)
   1 gallon = _____ liter(s)
   1 liter = _____ gallon(s)
   1 mile = _____ kilometer(s)
   1 kilometer = _____ mile(s)
   1 kilogram = _____ pound(s)
   1 pound = _____ kilogram(s)

SELF PROJECT

When you buy your steel scale, try to find one indicating inches on one side and centimeters on the other. Then you can use the one scale for both United States Customary and metric measurements. Add a foot ruler, a tape measure, and a yardstick to your tools. Many automotive-parts dealers give away extra-wide yardsticks with numbered holes in them. The purpose of the holes is to hold and to keep in order the valves you remove from an engine.

two SMALL ENGINES

This part of *Small-Engine Mechanics* describes the construction and operation of small engines. Two-cycle, four-cycle, and Wankel engines are discussed, along with basic engine principles and engine measurements. There are seven chapters in Part Two:



Chapter 8

Engine Principles

After studying this chapter, you should be able to:

1. **Describe the parts of the atom**
2. **Explain the combustion process**
3. **Discuss change of state**
4. **Define "pressure" and "vacuum"**

○ 8-1 ATOMS You might think it strange for us to start this chapter on engine principles with an explanation of atoms. But an engine will not run until atoms start getting together inside the engine. Therefore, we should take a close look at atoms.

You can make a long list of all the different things you see around you: this book, your chair, the window, the trees or buildings outside, the clouds, and so on. All these things are made of metal, wood, paper, glass, cloth, leather, clay, water, air, and thousands of other materials. But amazingly enough, all these different things are made of only a few kinds of basic "building blocks," called atoms. Atoms are not really "blocks," as we will learn when we study them. There are only about 100 different kinds of atoms. But these 100 kinds of atoms can be put together in millions of different ways to form millions of different substances. You can compare them with the 26 letters of our alphabet. These letters can be put together in many different ways to make up the several hundred thousand words in our language.

Now about those 100 or so kinds of atoms: We have special names for each kind, such as copper, iron, carbon, oxygen, silver, gold, uranium, aluminum, and mercury. The silver in a coin in your pocket is made up of an almost countless number of one kind of atom. The oxygen in the air you breathe and in the water you drink is made up of a vast number of another kind of atom. Any substance made up of only one kind of atom is called an element. Silver is an element. So are oxygen, hydrogen, sodium, and all the others listed in the table of elements (Fig. 8-1). Actually, the table lists only a few of the more common elements.

○ 8-2 SIZE OF ATOMS Atoms are very small. In a single drop of water there are more than 100 billion billion atoms. This is about 30 billion atoms for every person living on the earth. If you tried to count your share—your 30 billion atoms—it would take you 1000

TABLE OF ELEMENTS

Name	Symbol	Atomic number	Approximate atomic weight	Electron arrangement
Aluminum	Al	13	27	·2)8)3
Calcium	Ca	20	40	·2)8)8)2
Carbon	C	6	12	·2)4
Chlorine	Cl	17	35.5	·2)8)7
Copper	Cu	29	63.6	·2)8)18)1
Hydrogen	H	1	1	·1
Iron	Fe	26	56	·2)8)14)2
Magnesium	Mg	12	24	·2)8)2
Mercury	Hg	80	200	·2)8)18)32)18)2
Nitrogen	N	7	14	·2)5
Oxygen	O	8	16	·2)6
Phosphorus	P	15	31	·2)8)5
Potassium	K	19	39	·2)8)8)1
Silver	Ag	47	108	·2)8)18)18)1
Sodium	Na	11	23	·2)8)1
Sulfur	S	16	32	·2)8)6
Zinc	Zn	30	65	·2)8)18)2

FIG. 8-1 Table of some of the more common elements.

years if you counted one atom every second, day and night. And this is only your share of just one drop of water.

○ 8-3 INSIDE THE ATOM Now let us, in our imagination, look inside atoms to see what they are made of. You are likely to be disappointed. For there is almost nothing inside the atoms. For example, let us examine the hydrogen atom. It is made up of only two particles. One of these is at the center, or nucleus, of the atom. The other, a comparatively long distance away, is whirling in an orbit around the nucleus. The center particle is called a proton. The outside particle, in orbit around the proton, is called an electron.

The proton has a tiny charge of positive electricity, indicated by a plus (+) sign. The electron has a tiny charge of negative electricity, indicated by a minus (−) sign. Opposites attract. Minus attracts plus. Plus attracts minus. The negatively charged electron is pulled toward the positively charged proton. But balancing this inward-pulling force is the outward pull of centrifugal force. This is somewhat like the balancing of forces you get when you whirl a ball on a rubber band in a circle around your hand (Fig. 8-2). The rubber band pulls the ball toward your hand. But the centrifugal force pushes the ball away. The result is that the ball moves in an orbit, or in a circle, around your hand.

○ 8-4 HELIUM The simplest atom is hydrogen. It has one proton and one electron. Next, as we go from the simplest to the more complex atoms, is helium, another gas. The helium atom has two protons (+ charges) in its nucleus and two electrons (− charges) circling the nucleus (Fig. 8-3). In addition, the nucleus

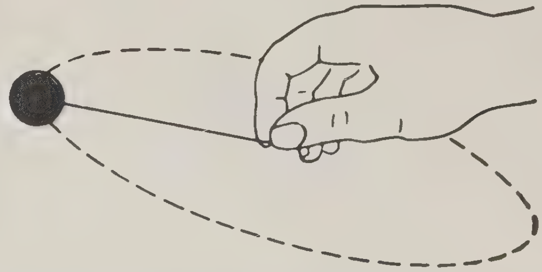


FIG. 8-2 The electron in a hydrogen atom circles the proton like a ball on a rubber band swung in a circle around the hand.

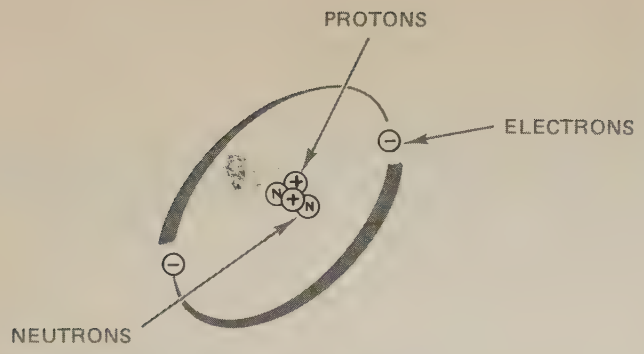


FIG. 8-3 Helium atom has two electrons, two protons, and two neutrons.

has two other particles which are electrically neutral (have no charge) and are therefore called neutrons. The neutrons weigh almost the same as the protons. They seem to serve as a sort of nuclear "glue" to keep the two protons together in the nucleus. Like electrical charges repel each other, and, without the neutrons, the protons would fly apart. But the presence of the neutrons in the nucleus seems to nullify this repulsive force between the protons so that they stay together inside the nucleus.

○ 8-5 MORE COMPLEX ATOMS The next element after helium in complexity is lithium, a very light metal. The lithium atom has a nucleus with three protons and four neutrons. Three electrons, one for each proton, circle the nucleus.

Next is beryllium, another metal, with four protons, four neutrons, and four electrons; boron with five protons, five neutrons, and five electrons; carbon with six, six, and six; nitrogen with seven, seven, and seven; oxygen with eight, eight, and eight; and so on. Each atom normally has the same number of electrons as protons. This makes the atom electrically neutral, since negative charges equal positive charges. However, some kinds of atoms are not always able to hold on to all their electrons. In these atoms some electrons may "wander" off, leaving electrically unbalanced atoms behind (with + charges). The ability of electrons to free themselves from atoms in this manner gives the phenomenon of electricity.

○ 8-6 CHEMICAL REACTIONS When two or more atoms link up, or combine, they form a molecule. The linking-up process is called chemical reaction. For example, two atoms of hydrogen and one atom of oxygen react to form one molecule of water (Fig. 8-4). Water has the chemical formula H_2O, which means each molecule has two atoms of hydrogen and one atom of oxygen. When one atom of sodium (chemical symbol Na) unites with one atom of chlorine (chemical symbol Cl), a molecule of common table salt is formed (NaCl). Another example is sugar, each molecule of which has 12 atoms of carbon, 22 atoms of hydrogen, and 11 atoms of oxygen and the chemical formula $C_{12}H_{22}O_{11}$.

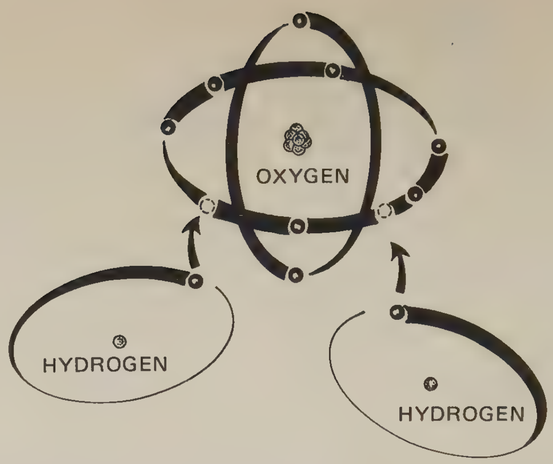


FIG. 8-4 One atom of oxygen uniting with two atoms of hydrogen to form a molecule of water, or H_2O.

During a chemical reaction, one or more of the electrons in the outer shells of some of the atoms are shared with other atoms. This matter of sharing will become clearer as we discuss electron shells, or orbits.

○ 8-7 COMBUSTION Combustion, or fire, is a common chemical reaction in which the gas oxygen combines with other elements, such as hydrogen or carbon. one type of combustion occurs in the small engine. A mixture of air and gasoline vapor is compressed and then ignited, or set on fire. The air is about 20 percent oxygen. Gasoline is mostly hydrogen and carbon (and therefore is called a hydrocarbon). The chemical reaction during combustion is between the three elements oxygen, hydrogen, and carbon.

We have seen how one oxygen atom combines with two hydrogen atoms to form H_2O, or water. Similarly, one carbon atom combines with two oxygen atoms to form a molecule of CO_2, or carbon dioxide (Fig. 8-5). Carbon dioxide is a gas. The carbon atom has six electrons in two shells: two electrons in the inner shell and four in the outer shell. When an atom of carbon combines with two atoms of oxygen, each oxygen atom takes two of the carbon atom's outer-shell electrons.

○ 8-8 HEAT Combustion is accompanied by high temperatures or "heat." From the scientific point of view, heat is simply the rapid motion of atoms or molecules in a substance.

The atoms and molecules of any substance are in rapid motion. Even though a piece of iron appears solid and motionless, the atoms and molecules in the iron are in rapid motion. The atoms in a piece of hot iron are moving faster than those in a piece of cold iron.

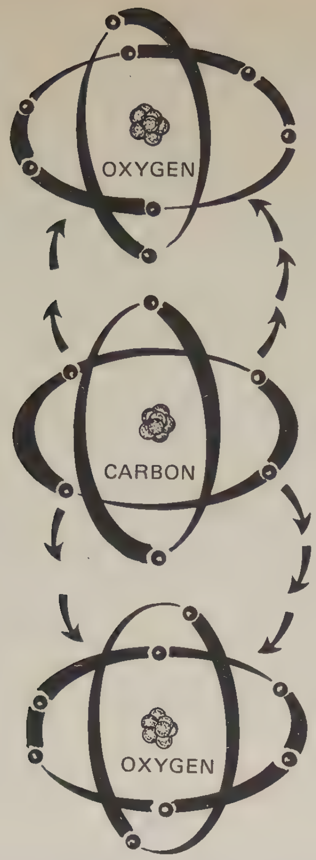


FIG. 8-5 Two atoms of oxygen uniting with one atom of carbon to form a molecule of carbon dioxide, or CO_2.

○8-9 CHANGE OF STATE If we put a pan of ice cubes over a fire, the ice cubes soon melt, or turn to water. Then the water boils, or turns to vapor. Most substances can exist in any of three states: solid, liquid, or gas (vapor). When a substance changes from one state to another, it undergoes a change of state.

A change in the speed of molecular motion, if great enough, results in a change of state. For example, in ice, the water molecules are moving slowly and in restricted paths. But as the temperature increases, the molecules move faster and faster. Soon the molecules are moving so fast they they break out of their restricted paths. The ice turns to water at 32°F [0°C]. As molecular speed increases still more, the boiling point is reached: 212°F [100°C] at sea level. Now the molecules are moving so fast that great numbers of them fly clear out of the water. The water boils, or turns to vapor.

○8-10 PRODUCING CHANGE OF STATE What makes the water molecules move faster? During combustion, oxygen unites with carbon or hydrogen atoms. The new molecules formed are set into extremely rapid motion. The rushing together of the atoms to satisfy the unbalance of electric charges can be said to produce this rapid motion. Now the newly formed and rapidly moving molecules from the fire below the pan bombard the pan. This bombardment sets the molecules of metal in the pan into rapid motion. The pan becomes hot. The metal molecules, in turn, bombard the ice molecules. The ice melts and then turns to vapor.

○8-11 LIGHT AND HEAT RADIATIONS This is only a partial description of what takes place during combustion. In addition to the swiftly moving molecules, the fire also produces radiations. We can see these radiations as light and feel them as heat. They are produced by certain actions inside the atoms of fuel and oxygen. A partial explanation of these actions is that the inner electrons of the atoms are disturbed by the actions of the outer electrons as they move between atoms. The inner electrons jump between shells. Each jump is accompanied by a tiny flash of radiant energy.

○8-12 EXPANSION OF SOLIDS WITH HEAT When a piece of iron is heated, it expands. A steel rod that measures 10 feet [3.048 m] in length at 100°F [37.8°] will measure 10.07 feet [3.069 m] in length at 1000°F [537.8°C] (Fig. 8-6). As the rod is heated, the molecules in it move faster and faster. They need more room to do so and therefore push adjacent molecules away so that the rod gets longer.

○8-13 EXPANSION OF LIQUIDS AND GASES WITH HEAT Liquids and gases also expand when heated. One cubic foot of water at 39°F [3.89°C] will become, when heated to 100°F [37.8°C], 1.01 cubic feet. A cubic foot is a cube measuring one foot on each side. A cubic foot of air at 32°F [0°C] heated to 100°F [37.8°C] without a change of pressure will become 1.14 cubic feet. These expansion effects result from more rapid molecular motion, which tends to push the molecules farther apart so that they spread out and take up more room.

○8-14 INCREASE OF PRESSURE A different sort of effect results if the volume is held constant while the cubic foot of air is heated from 32 to 100°F [0 to 37.8°C]. If we start with a pressure of 15 pounds per square inch [103 kPa], the pressure increases to about

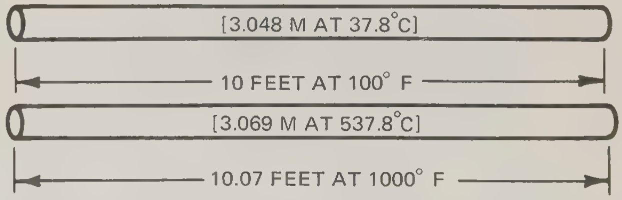


FIG. 8-6 A steel rod that measures 10 feet [3.048 m] at 100°F [37.8°C] will measure 10.07 feet [3.069 m] at 1000°F [537.8°C].

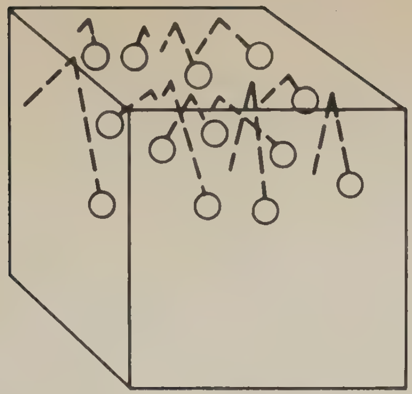


FIG. 8-7 Gas pressure in a container is the result of the ceaseless bombardment of the inner sides of the container by the fast-moving molecules of gas. For simplicity, this bombardment is shown on only one side of the container. Actually, the bombardment takes place against all inside surfaces. The molecules are shown greatly enlarged. There are billions of molecules in action—not just the few shown here.

17 psi [117 kPa] at 100°F [37.8°C]. This can also be explained by the molecular theory of heat.

Gas pressure in a container is due entirely to the unending bombardment of the gas molecules against the inside of the container (Fig. 8-7). Gas molecules move about in all directions at high speeds. They are continually bumping into one another and into any solid that is in their way. The walls of the container are bumped by these billions of molecules. These "bumps" add up to a combined push, or pressure.

As temperature increases, the molecules of gas move faster. They bump the walls of the container harder and more often. The result is higher pressure in the container.

Another way to increase pressure in a container is to compress the gas in the container into a smaller volume. This is what happens in engine cylinders. The mixture of air and gasoline vapor is squeezed to about one-eighth or one-ninth of its original volume. The molecules then move much faster, hitting the cylinder head and piston more often and faster. The pressure goes up.

○ 8-15 INCREASE OF TEMPERATURE Pressure and temperature increase when a gas is compressed. Moving the molecules closer together causes them to bump into one another more often so that they are set into faster motion. Faster motion means a higher temperature. For example, in the diesel engine, air is compressed to as little as one-sixteenth of its original volume. This raises the temperature of the air to about 1000°F [537.8°C]. The heat produced by the action soon escapes from the compressed air and its container into the surrounding air. Any hot object loses heat until its temperature falls to that of the surrounding medium.

○ 8-16 THE THERMOMETER The thermometer (Fig. 8-8) shows a familiar use of the expansion of liquids as temperature goes up. The liquid, usually mercury (a metal that is liquid at ordinary temperatures), is largely contained in the glass bulb at the bottom of the glass tube. As temperature increases, the mercury expands. Part of it is forced up through the hollow glass tube. The higher the temperature, the more the mercury expands and the higher it is forced up through the tube. The tube is marked off to indicate the temperature in degrees.

○ 8-17 THE THERMOSTAT Different metals expand at different rates with increasing temperatures. Aluminum expands about twice as much as iron as their temperatures go up. This difference in expansion rates is used in thermostats. Thermostats do numerous jobs in small engines and in automobiles. One type consists of a coil made up of two strips of different metals, such as brass and steel, welded together. When the coil is heated, one metal expands faster than the other, causing the coil to wind up or unwind.

○ 8-18 GRAVITY Gravity is the attractive force between all objects. When we release a stone from our hand, it falls to earth. When a car is driven up a hill, part of the engine power is being used to lift the car against gravity. Likewise, a car can coast down a hill with the engine turned off, because gravity pulls downward on the car.

Gravitational attraction is usually measured in terms of weight. We put an object on a scale and see

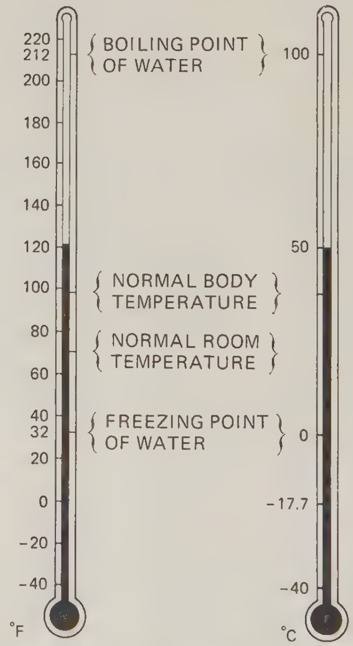


FIG. 8-8 Thermometers comparing Fahrenheit and Celsius (also called centigrade) readings.

that it weighs 10 pounds [4.5 kg]. What we mean is that the object has sufficient mass for the earth to register this much pull on it. Gravitational attraction gives any object its weight.

○ 8-19 ATMOSPHERIC PRESSURE The air is also an "object" that is pulled toward the earth by gravity. At sea level and average temperature, one cubic foot of air weighs about 0.08 pound, or about 1.25 ounce. This seems like very little. But the blanket of air—our atmosphere—surrounding the earth is many miles thick. This means that there are, in effect, many thousands of cubic feet of air piled on top of one another, all adding their weight. The total weight, or downward push, of this air amounts to about 15 psi [103 kPa] at sea level. The pressure of all this air pushing downward is about 2160 pounds [980 kg] on every square foot. Since the human body has a surface area of several square feet, it has a total pressure of several tons on it.

It would seem that this tremendous pressure would crush you. The reason that it does not is that the internal pressures inside the body balance the outside pressure.

○ 8-20 VACUUM A vacuum is the absence of air or any other matter. Astronauts, on their way to the moon and the other planets, soon leave the blanket of air surrounding the earth and pass into the vast region of empty space. Out in space, there are only a few scattered atoms of air. This is a vacuum.

○ 8-21 PRODUCING A VACUUM There are many ways to produce a vacuum. The engine, as it operates, produces a partial vacuum in the engine cylinder. The fuel pump works by producing a partial vacuum.

1. *Barometer.* The mercury barometer (Fig. 8-9) is another device that utilizes a vacuum. You can make a barometer by filling a long tube with mercury and then closing the end. Next, turn the tube upside down, and put the end in a dish of mercury. Now open the end. Some of the mercury will run down out of the tube, leaving the upper end of the tube empty (a vacuum).

   The barometer is used to measure atmospheric pressure. When atmospheric pressure increases, the increased push on the mercury forces it higher in the tube (Fig. 8-10). When atmospheric pressure goes down, the mercury also goes down in the tube. The barometer is used to forecast weather. Before a storm, the atmospheric pressure usually drops. This is because of the heated and therefore lighter air accompanying a storm. When the mercury falls in the barometer, it indicates that a storm is coming.

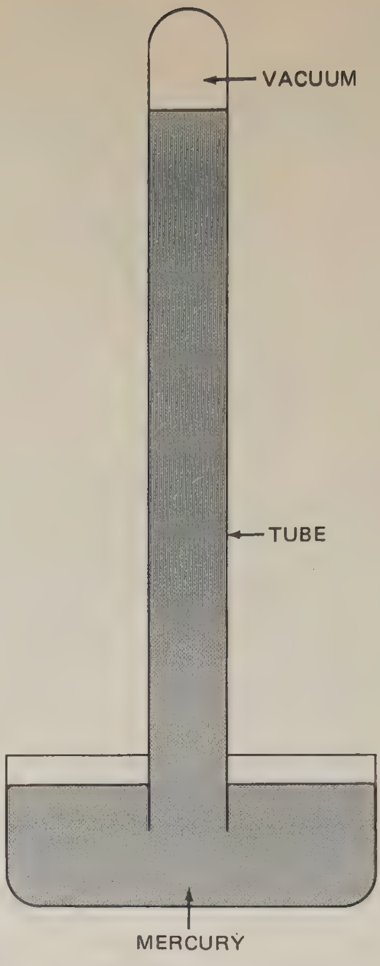


FIG. 8-9 Barometer. The mercury in the tube will stand at about 30 inches [762 mm] above the surface of the mercury in the dish at an atmospheric pressure of 15 psi [1.05 kg/cm^2].

2. *Vacuum Gauge.* The vacuum gauge is really a pressure gauge. The type of vacuum gauge used in engine service contains a bellows or diaphragm which is linked to an indicating needle on the dial face (Fig. 8-11). When the vacuum gauge is connected to the engine (to the intake

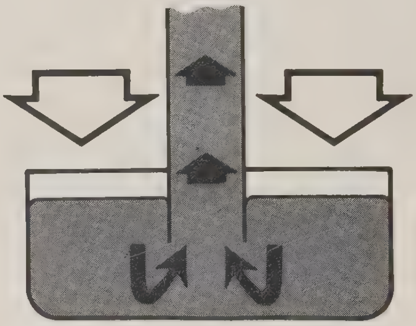


FIG. 8-10 The pressure of the air, acting on the surface of the mercury and through the mercury, holds the mercury up in the tube. If the air pressure increases, the mercury will be forced higher in the tube.

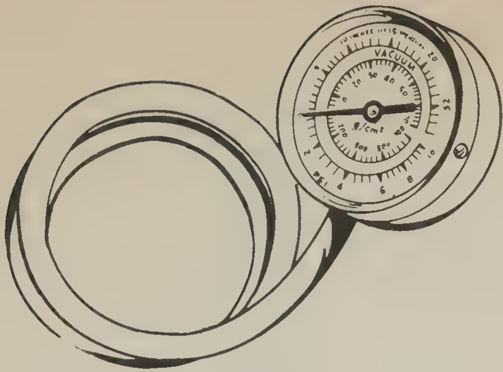


FIG. 8-11 A vacuum gauge. *(Onan Corporation)*

manifold), the vacuum produced by the engine causes the needle to move and register the amount of vacuum. This action results because the vacuum causes part of the air in the bellows or back of the diaphragm to pass into the engine. Then air pressure causes the bellows or diaphragm to move, thereby causing the needle to move. The amount that the needle moves depends on the amount of vacuum. The amount of vacuum that a running engine can produce is a measure of engine condition. The vacuum gauge is a good diagnostic tool to determine the actual condition of the engine. This is discussed in detail in a later chapter.

REVIEW QUESTIONS

1. What are molecules?
2. What are the major parts of atoms?
3. What is a chemical reaction?
4. What is combustion?
5. What does the term "change of state" mean?
6. Describe combustion in the engine cylinder.
7. Explain what heat is in terms of molecular motion.
8. Explain gas pressure in terms of molecular action.
9. Why does the gas pressure in a container increase with increasing temperature?
10. What is atmospheric pressure?
11. Explain how a barometer works.
12. What is vacuum?
13. What is a coil thermostat? How does it work?
14. What is atmospheric pressure? What causes it?

SELF PROJECT

For complete small-engine servicing, several thermometers are needed to measure various temperatures. For example, you may need to know the temperature of the electrolyte (liquid in the battery) when checking the battery state of charge. You may need to measure the temperature of the coolant (liquid) in the engine cooling system. Other temperatures to be measured include the cooling-system-thermostat operating temperature, operating temperature of the thermostat in the carburetor air cleaner, and so on. As you study the later chapters in the book, you will find explanations of the various temperature readings and how to take them. You cannot use any one thermometer to take all these different measurements. Therefore, if you are going to be an expert mechanic, you will need several thermometers. Collect them as you go along and keep them in a safe place in your toolbox.

Chapter 9

Two-Cycle-Engine Operation

After studying this chapter, you should be able to:

1. Describe the actions of the piston and rings
2. Explain the strokes of the two-cycle engine
3. Define "crankcase compression"

○ 9-1 INTERNAL COMBUSTION Before we explain what two-cycle and four-cycle mean, we want to mention that both of these engines are internal-combustion engines. The combustion, or fire, that makes the engines go takes place inside the engine. This is in contrast to the steam engine. The fire for this engine takes place outside the engine, in a separate boiler. The boiler boils water to produce steam. Then the steam enters the steam engine to make it run. The steam engine is called an external-combustion engine because the combustion, or fire, that makes it run takes place outside the engine.

Now, back to internal-combustion engines—two-cycle and four-cycle. We will look at the two-cycle engine first because it is simpler in construction, has fewer internal parts to wear, and is the most widely used engine for such equipment as power lawn mowers, edgers, tillers, chain saws, and so on. However, there are many small four-cycle engines in operation. Almost all automotive engines are of the four-cycle type. We will explain the basic differences between these types of engines later. First, however, let us look at the two-cycle engine.

○ 9-2 THE PISTON AND THE CYLINDER Imagine a tin can with one end cut out (Fig. 9-1*a*). Imagine a second tin can slightly smaller in size which will fit snugly into the first can, as shown in Fig. 9-1*b*. Now suppose you pushed the smaller can rapidly up into the larger can, trapping air ahead of it. This air would be pushed into a smaller space than it had previously occupied. The air would be compressed. If the air contained a small amount of gasoline vapor, and if an electric spark were applied to this compressed air-fuel mixture, there would be an explosion. The smaller can would be blown out of the larger can. This action is shown in Fig. 9-1*c*.

This is about what happens in the internal-combustion engine except that the smaller can is not blown all the way out. Instead, in the actual engine, there is

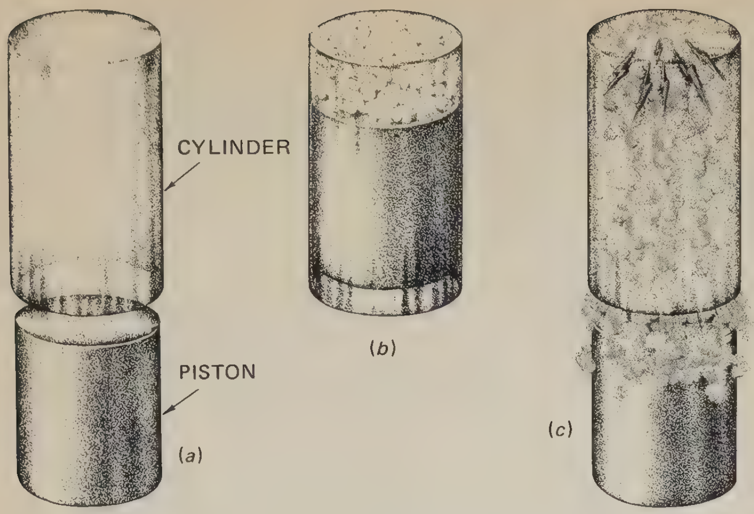


FIG. 9-1 Three views showing the actions in an engine cylinder. (a) This piston is a metal plug that fits snugly into the engine cylinder. (b) When the piston is pushed up into the cylinder, air is trapped and compressed. The cylinder is drawn as though it were transparent so that the piston can be seen. (c) The increase of pressure as the gasoline vapor and air mixture is ignited pushes the piston out of the cylinder.

an arrangement to prevent this. In the engine, the larger can is called the cylinder. The smaller can is called the piston. The piston slides up and down in the cylinder.

○ 9-3 THE ENGINE CYLINDER

The engine cylinder is a round hole in a block of metal. Most small engines have only one cylinder. Some have two cylinders. Also, some engines classified as "small" have four cylinders. There is no set rule about how many cylinders a small engine should have, as opposed to a "big" engine. Regardless of how many cylinders an engine has, the same actions go on in each cylinder. Each cylinder has a piston that slides up and down in it.

○ 9-4 PISTON RINGS

The piston must be a fairly loose fit in the cylinder. If the piston fits too tightly, it would expand as it got hot and would stick in the cylinder. If the piston sticks, it could ruin the engine. But if there is too much clearance between the piston and cylinder wall, here is what would happen: Much of the pressure from the burning gasoline vapor would leak past or "blow by" the piston (Fig. 9-2). This means that there would be less push on the piston. It is the push on the piston that delivers the power from the engine. *Blow-by* means loss of engine power.

To provide a good seal between the piston and cylinder wall, piston rings are used, as shown in Fig. 9-3. So that the piston rings can be fitted to the piston, two or more grooves are cut into the upper part of the piston, as shown in Fig. 9-3. These are called the piston-ring grooves. The rings are made of cast iron or other metal. They are split at one point so they can be expanded and slipped over the ends of the piston and into the ring grooves cut in the piston. Pistons for two-cycle engines usually have two rings which are pinned or locked in place. This prevents the end of the ring from catching in a port and breaking. Four-cycle engine pistons usually have three rings which are free to move around in their ring grooves.

When the piston, with rings, is installed in the cylinder, the rings are compressed into the ring grooves so that the split ends come almost together. The rings fit tightly against the cylinder wall and

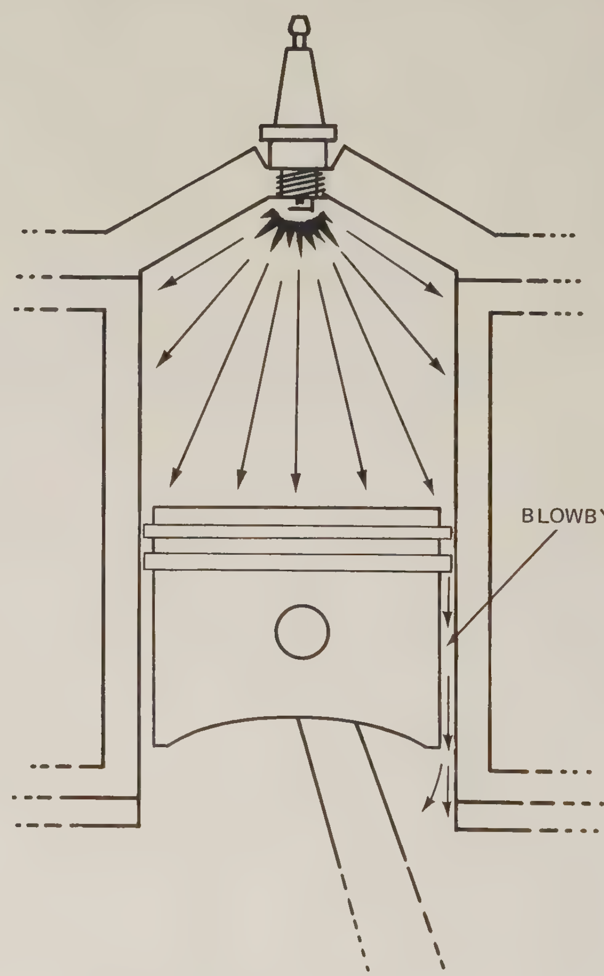


FIG. 9-2 If the piston fits too loosely in the cylinder, much of the pressure will be lost as the exploding mixture leaks past, or "blows by," the piston.

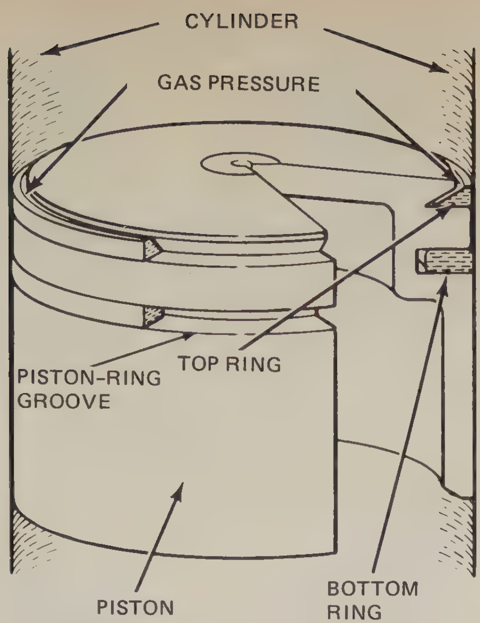


FIG. 9-3 Typical piston with piston rings in place. When the piston is installed in the cylinder, the rings are compressed into the grooves in the piston. *(Lawn Boy Division of Outboard Marine Corporation)*

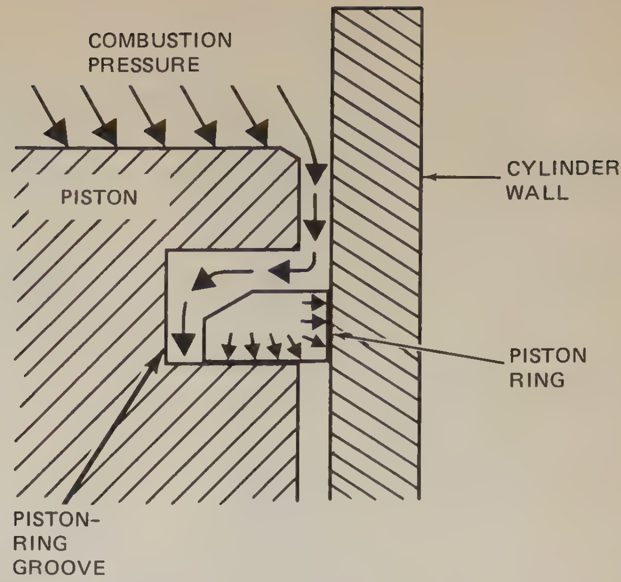


FIG. 9-4 Pressure in the combustion chamber above the piston, either from compression of the air-fuel mixture or from its combustion, presses the ring against the cylinder wall and the lower side of the piston-ring groove.

against the sides of the ring grooves in the piston. They form a good seal between the piston and the cylinder wall. The rings can expand or contract as they heat and cool and still make a good seal. They are free to slide up and down the cylinder wall. In the two-cycle engine, oil is mixed with the gasoline and this mixture enters the crankcase, as we will explain later. The gasoline goes on into the combustion chamber, where it is burned. Part of the oil covers the cylinder wall so the wall is kept coated with oil. This allows the rings and pistons to slide up and down the wall easily, with little friction. We discuss oil and friction in a later chapter.

Figure 9-4 shows how the piston ring works to hold in the compression and combustion pressures. The arrows show the pressure from above the piston passing through the clearance between the piston and the cylinder wall. It presses down against the top and against the back of the piston ring, as shown by the arrows. This pushes the piston ring firmly against the cylinder wall and also against the bottom of the piston-ring groove. As a result, there are good seals at both of these points. The higher the pressure in the combustion chamber, the better the seal.

Small two-cycle engines usually have two rings on the piston. Both are compression rings. Two rings are used to divide up the job of holding the compression and combustion pressures. This produces better sealing with less ring pressure against the cylinder wall. Some two-cycle engines, such as certain motorcycle engines, have only one piston ring.

Four-cycle engines have an extra ring, called the oil-control ring. Four-cycle engines are so constructed that they get much more oil in the cylinder wall than do two-cycle engines. This additional oil must be scraped off to prevent it from getting up into the combustion chamber, where it would burn and cause trouble.

Some four-cycle-engine pistons have four rings. The engine design requires this added ring for adequate oil control. We will discuss this further in Chap. 11.

○ 9-5 THE CRANK The piston moves up and down in the cylinder. This up-and-down motion is called reciprocating motion. The piston moves in a straight line. This straight-line motion must be changed to rotary, or turning motion, in most machines, before it can do work. Rotary motion is required to make wheels turn, a cutting blade spin, or a pulley rotate. To change the reciprocating motion to rotary motion, a crank and connecting rod are used (Figs. 9-5 and 9-6). The connecting rod connects the piston to the crank.

The crank is a very common device which is used in many machines and in almost all engines. The crank is an offset part of a shaft. When the shaft rotates, the crank and crankpin swing in a circle as shown in Fig. 9-7. When the piston is pushed down in the cylinder by the combustion pressures, the push on the piston, carried through the connecting rod to the crank, causes the shaft to turn. Figure 9-8 shows the motions that the piston, connecting rod, and crank go through. As the piston moves up and down, the top end of the connecting rod moves up and down with it. The bottom end of the connecting rod swings in a circle along with the crank.

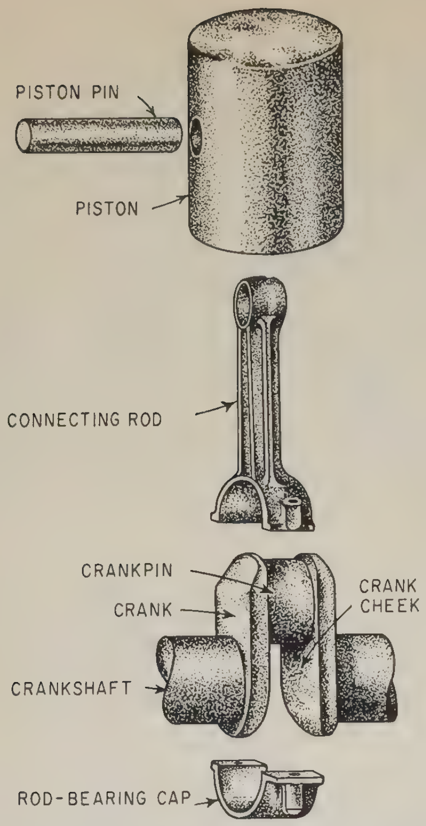


FIG. 9-5 Piston, connecting rod, piston pin, and crankpin on an engine crankshaft in disassembled view. The piston rings are not shown.

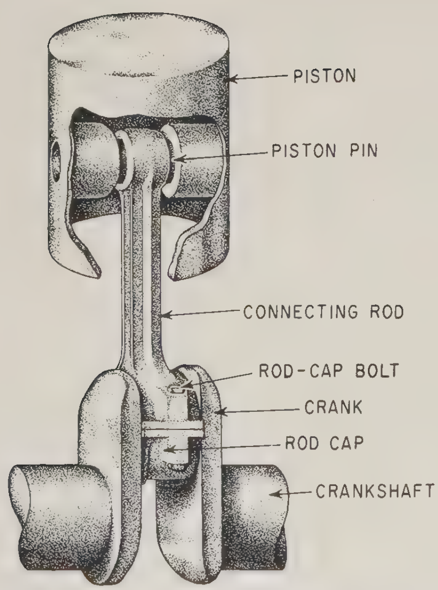


FIG. 9-6 Piston and connecting-rod assembly attached to the crankpin on a crankshaft. The piston rings are not shown. The piston is pictured as if cut away to show how it is attached to the connecting rod.

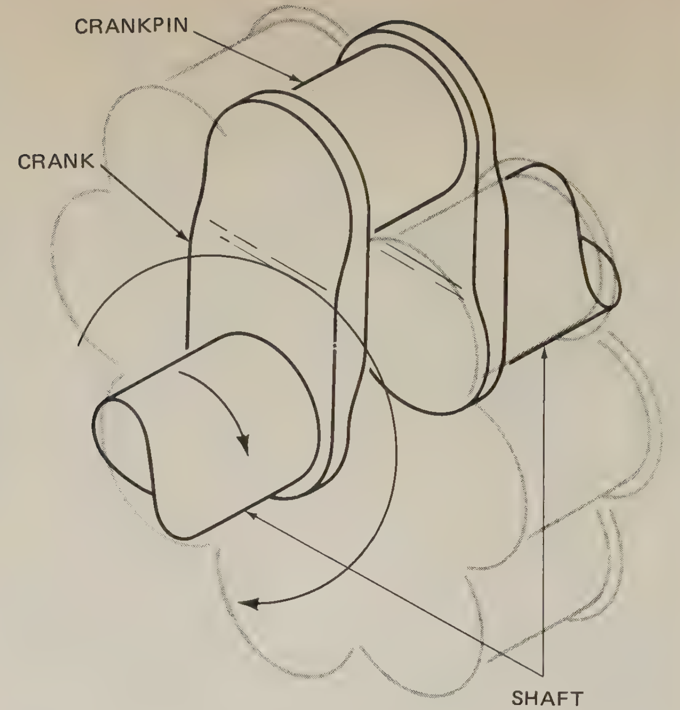


FIG. 9-7 As the crankshaft rotates, the crank and crankpin swing in a circle around the shaft.

The piston end of the connecting rod is attached to the piston by a piston pin, also called a wrist pin. The other end of the connecting rod is attached to the crankpin. There are bearings at both ends of the connecting rod so that the rod can move freely. We will discuss bearings later.

The crank end of the connecting rod is sometimes called the rod *big end*. The piston end of the connecting rod is sometimes called the rod *small end*. These terms are used in the shop and in some manuals.

○ 9-6 CRANKSHAFT

The crank is a part of the crankshaft. It is an offset section, as shown in Fig. 9-9, to which the connecting-rod big end is attached by a bearing. The crankshaft is mounted in the engine on bearings which allow the crankshaft to rotate. As the crank rotates, it swings in a circle, as shown in Fig. 9-8.

The crankshaft is assembled with flywheels, or counterweights, as shown in Fig. 9-9. These counterweights balance the weights of the crankpin and connecting rod to reduce the tendency of the crankshaft to go out-of-round when it is rotating. This makes for a smoother running engine and much less wear on the bearings which support the crankshaft.

○ 9-7 ENGINE BEARINGS

The crankshaft is supported by bearings. The connecting-rod big end is attached to the crankpin on the crank of the crankshaft by a bearing. A piston pin at the rod small end is used to attach the rod to the piston. The piston pin rides in bearings. Everywhere there is rotary action in

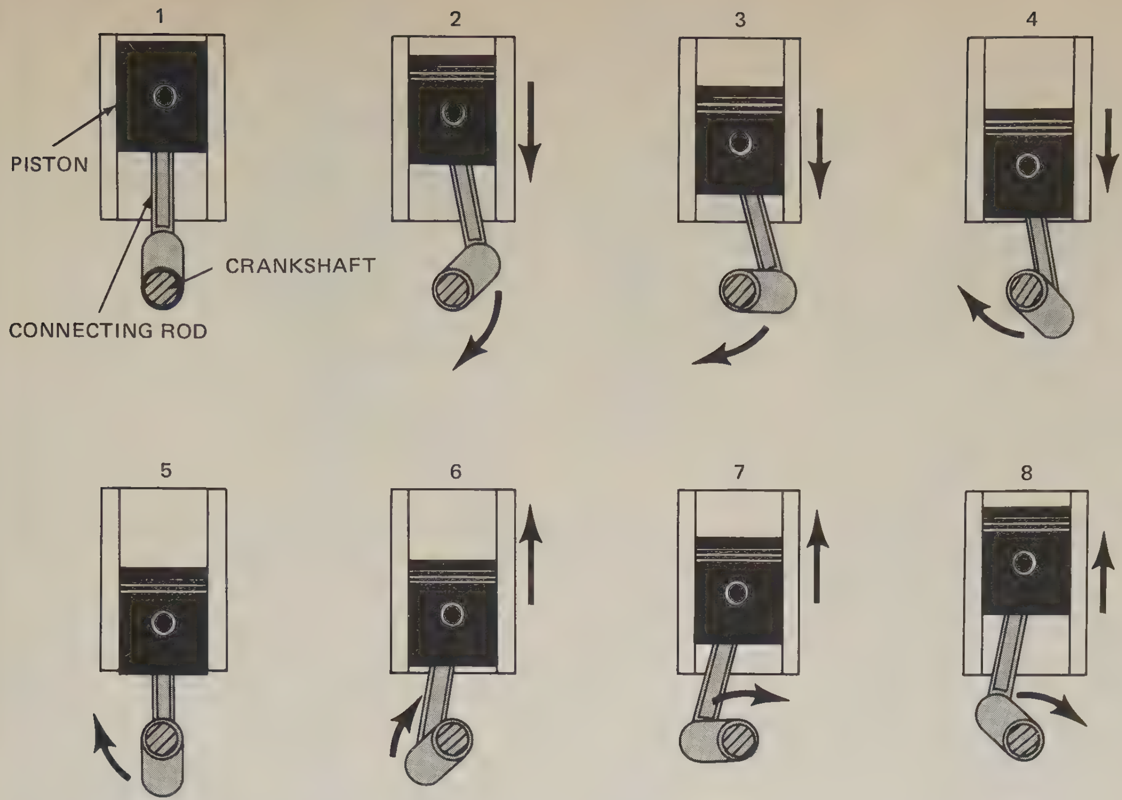


FIG. 9-8 Sequence of actions as the crankshaft completes one revolution and the piston moves from top to bottom to top again.

the engine, bearings are used to support the moving parts. The purpose of bearings is to reduce the friction and allow the parts to move easily. Bearings are lubricated with oil to make the relative motion easier. In Chapter 15, we discuss friction, engine oil, and the lubricating systems that get the oil to the moving parts.

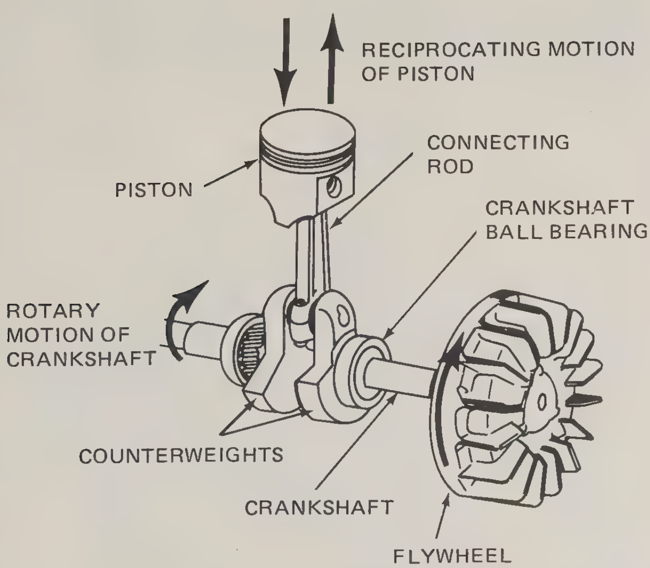


FIG. 9-9 The crankshaft converts the reciprocating motion to rotary motion. The crankshaft mounts in bearings which encircle the journals so it can rotate freely.

Bearings used in engines are of two types: sliding and rolling (Fig. 9-10). The sliding-type bearings are sometimes called bushings or sleeve bearings. They are in the shape of a sleeve that fits around the rotating journal, or shaft. The sleeve-type connecting-rod big-end bearings—usually called simply rod bearings—and the crankshaft supporting bearings—called the main bearings—are of the split-sleeve type. They are split to permit their easy assembly into the engine. In the rod bearing, the upper half of the bearing is installed in the rod. The lower half is installed in the rod-bearing cap. When the rod cap is fastened to the rod, as shown in Fig. 9-6, a complete sleeve bearing is formed. Similarly, the upper halves of the main bearings are assembled in the engine. Then the main-bearing caps, with the lower bearing halves, are attached to the engine to complete the sleeve bearings supporting the crankshaft.

The typical bearing half is made of a steel or bronze back to which a lining of relatively soft bearing material is applied (Fig. 9-11). This relatively soft bearing material, which is made of several materials, such as copper, lead, tin, and other metals, has the ability to conform to slight irregularities of the shaft rotating against it. If wear does take place, it is the bearing that wears. When that happens, the bearing can be replaced instead of the much more expensive crankshaft or other engine part.

The rolling-type bearing uses balls or rollers between the stationary support and the rotating shaft, as shown in Figs. 9-9, 9-10, and 9-12. Since the balls or rollers provide rolling contact, the frictional resis-

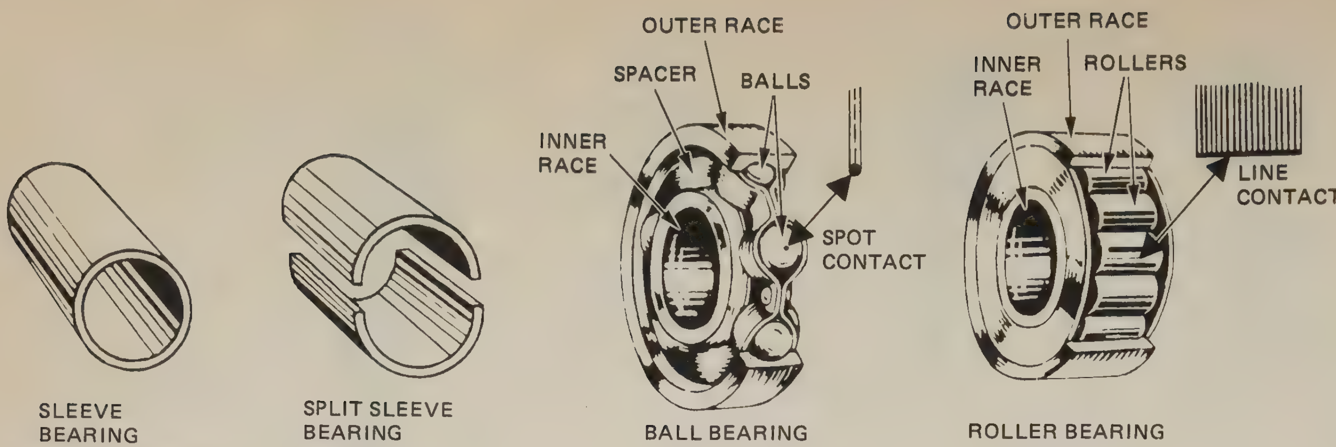


FIG. 9-10 Sleeve, ball, and roller bearings.

tance to movement is much less. In some roller bearings, the rollers are so small that they are hardly bigger than needles. These bearings are called needle bearings. Some roller bearings have the rollers set at an angle, and so the races the rollers roll in are tapered. These bearings are called tapered roller bearings (Fig. 9-12). Some ball and roller bearings are sealed with their lubricant already in place. Such bearings require no other lubrication. Others require lubrication from the oil in the gasoline (in two-cycle engines) or from the engine lubrication system (in four-cycle engines).

○ 9-8 MAKING THE ENGINE RUN In order to run, an engine must have a mixture of air and gasoline vapor. This mixture must enter the cylinder and be compressed by the piston as it moves up. Then a spark must occur in the cylinder so the mixture will be ignited. The mixture burns rapidly and pushes the piston down. This push is carried through the connecting rod, causing the crankshaft to turn. Next, the burned gases must be removed from the cylinder and a fresh charge of air-fuel mixture brought in. These actions continue as long as the engine runs. We will go into detail on these actions later.

○ 9-9 THE PISTON STROKE In any piston engine, the movement of the piston from one limiting position to the other is called a piston stroke. The upper limiting position of the piston is called top dead center (TDC), and the lower limiting position is called bottom dead center (BDC). A piston stroke takes place when the piston moves from TDC to BDC or from BDC to TDC (Fig. 9-13). When the piston moves from TDC to BDC, after combustion has taken place, the stroke is the power stroke. The high pressure of combustion, forcing the piston to move during the power stroke, results in power from the engine.

○ 9-10 HOW THE TWO-CYCLE ENGINE GOT ITS NAME The full name of the two-cycle engine is "two-stroke-cycle engine." The reason for this is that it takes two piston strokes, an up stroke and a down stroke, to complete a cycle of engine operation. Everything that happens in the engine takes place in these two strokes, and these events continue to be repeated as long as the engine runs. This is the

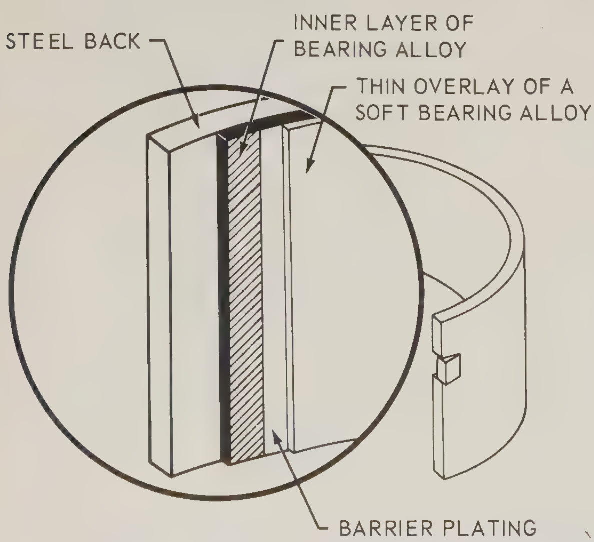


FIG. 9-11 Construction of a bearing half of the sleeve type. The softer bearing material is applied to a hard back. *(Federal-Mogul Corporation).*

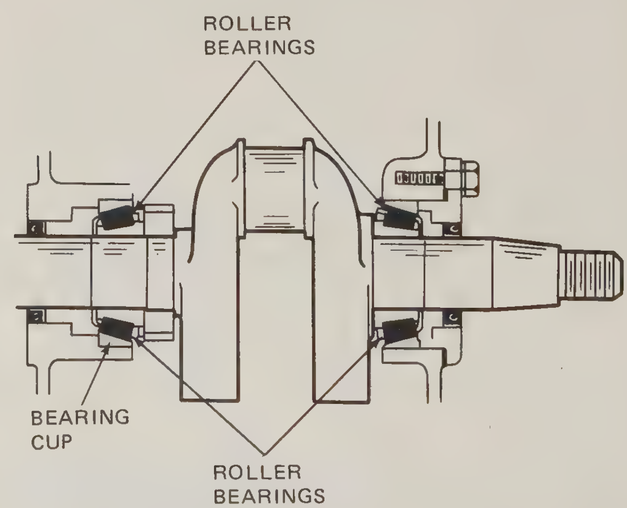


FIG. 9-12 Crankshaft mounted on tapered roller bearings. *(Kohler Company)*

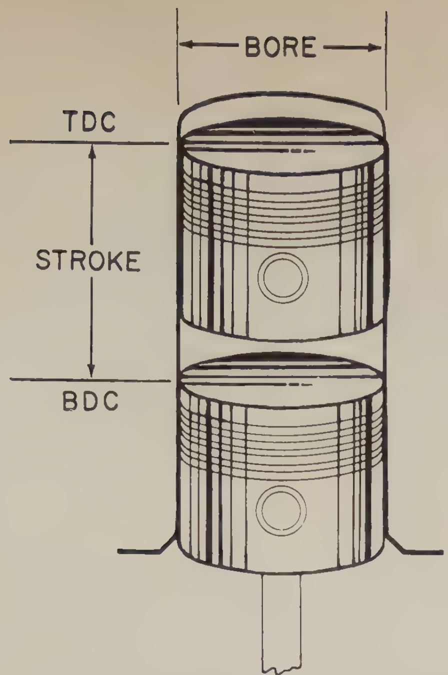


FIG. 9-13 The bore and stroke of an engine cylinder.

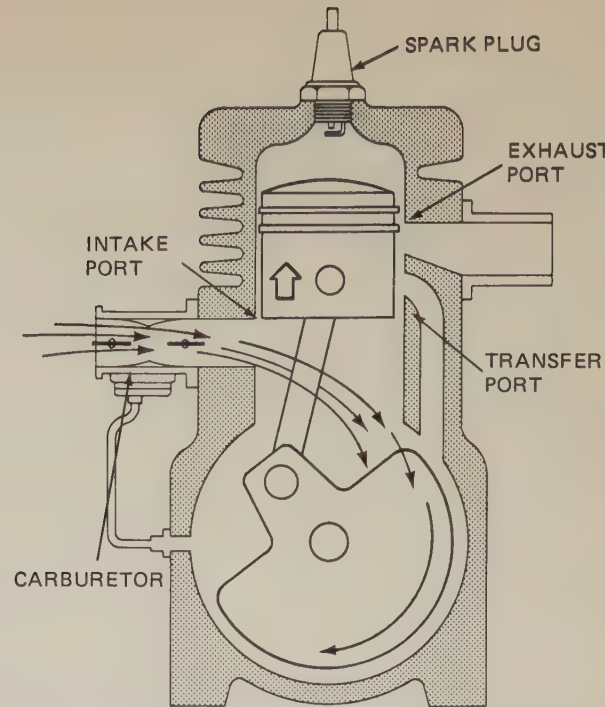


FIG. 9-15 As the piston moves up in the cylinder, the lower edge of the piston moves above the intake port. This allows fresh air-fuel mixture into the crankcase. *(Kohler Company)*

meaning of "cycle." A cycle is a series of events that repeat themselves. For example, the cycle of the seasons—spring, summer, fall, and winter—is repeated every year. In a similar way, the two piston strokes in the two-stroke-cycle engine form a cycle that is repeated continuously as the engine runs.

Sometimes the word "stroke" is used and the word "cycle" dropped, so that two-stroke-cycle engine has become, in common usage, "two-stroke engine." However, there are two piston strokes in a single cycle of the two-cycle engine.

○ 9-11 ENGINE ACTIONS The air-fuel mixture enters the cylinder, and burned gases leave the cylinder, through ports, or openings, in the cylinder wall. The port through which air-fuel mixture actually enters the cylinder is called the *transfer port*. The port through which the burned gases leave is called the *exhaust port*. The port through which the fresh air-fuel mixture flows from the carburetor into the crankcase is called the *intake port*. The reason that the air-fuel mixture first enters the crankcase and then transfers to the combustion chamber is discussed in the next section.

Figure 9-14 shows the locations of the ports in cutaway views of a cylinder for a two-cycle engine. Let us follow the complete sequence of actions in the engine, from the time that the fresh air-fuel mixture enters the crankcase.

As the piston moves up the cylinder, the lower edge of the piston moves above the intake port (Fig. 9-15). This clears or opens the port and allows air-fuel mixture to flow from the carburetor through the intake

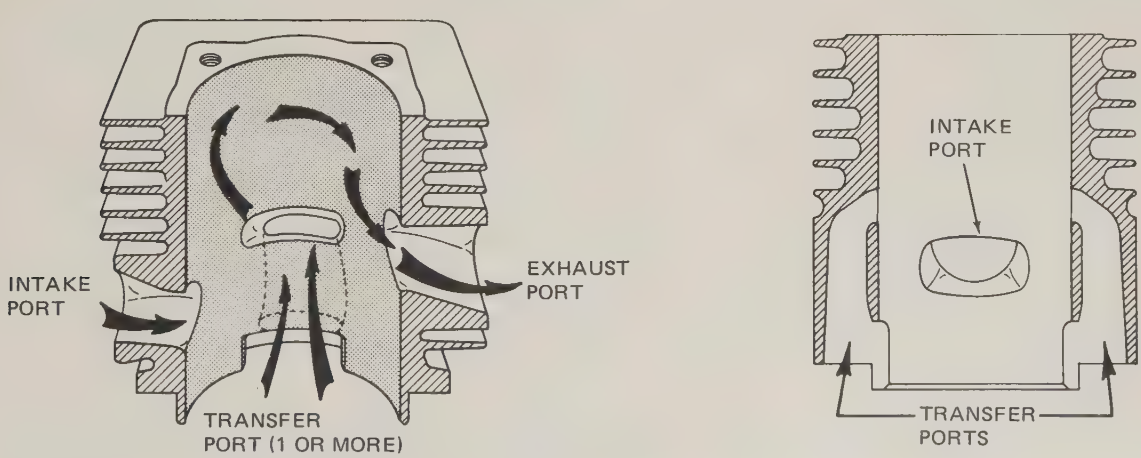


FIG. 9-14 Cutaway views of a cylinder showing the ports in a two-cycle engine. *(Kohler Company)*

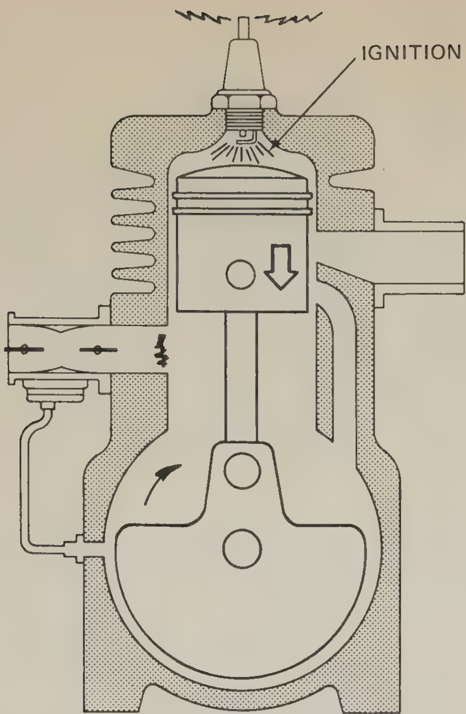


FIG. 9-16 As the piston nears TDC, ignition occurs. The resulting high combustion pressure forces the piston down. *(Kohler Company)*

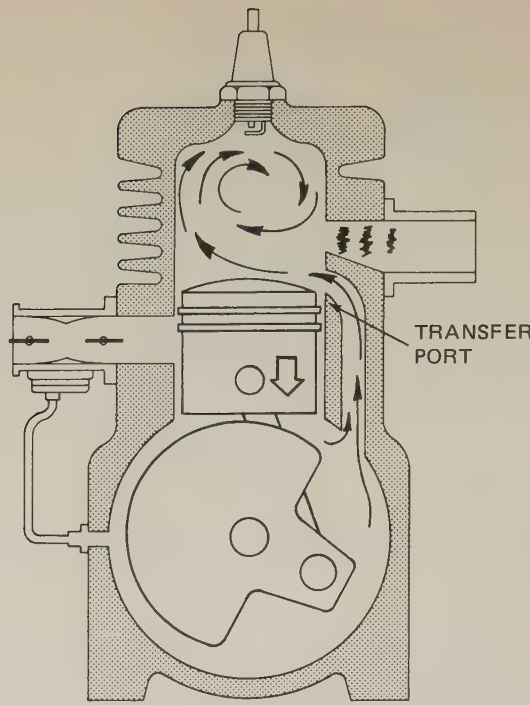


FIG. 9-18 As the piston nears BDC, it opens the transfer port, allowing fresh air-fuel mixture to flow from the crankcase into the cylinder. *(Kohler Company)*

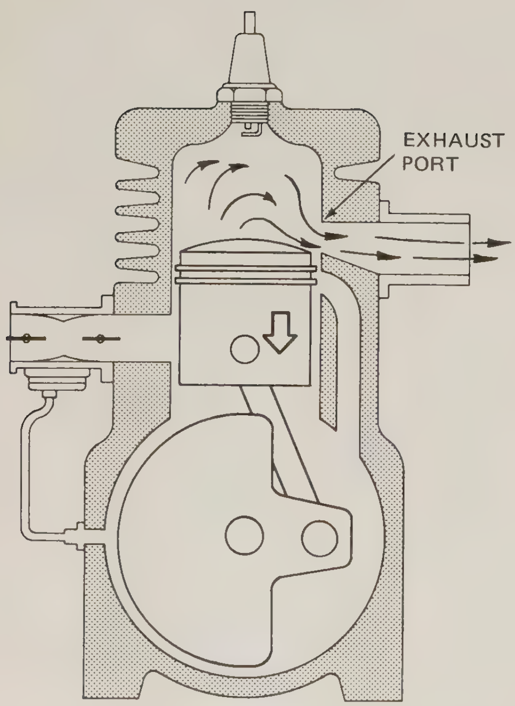


FIG. 9-17 As the piston moves down the cylinder, it opens the exhaust port, allowing the burnt exhaust gases to flow from the cylinder. *(Kohler Company)*

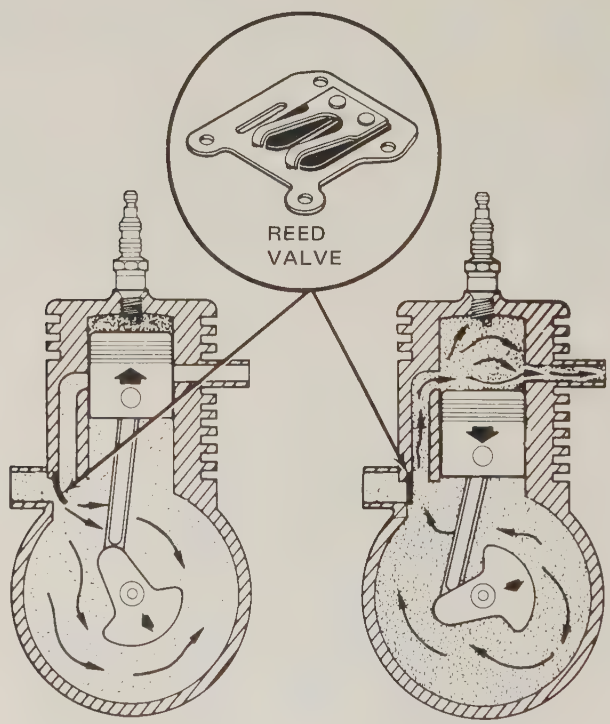
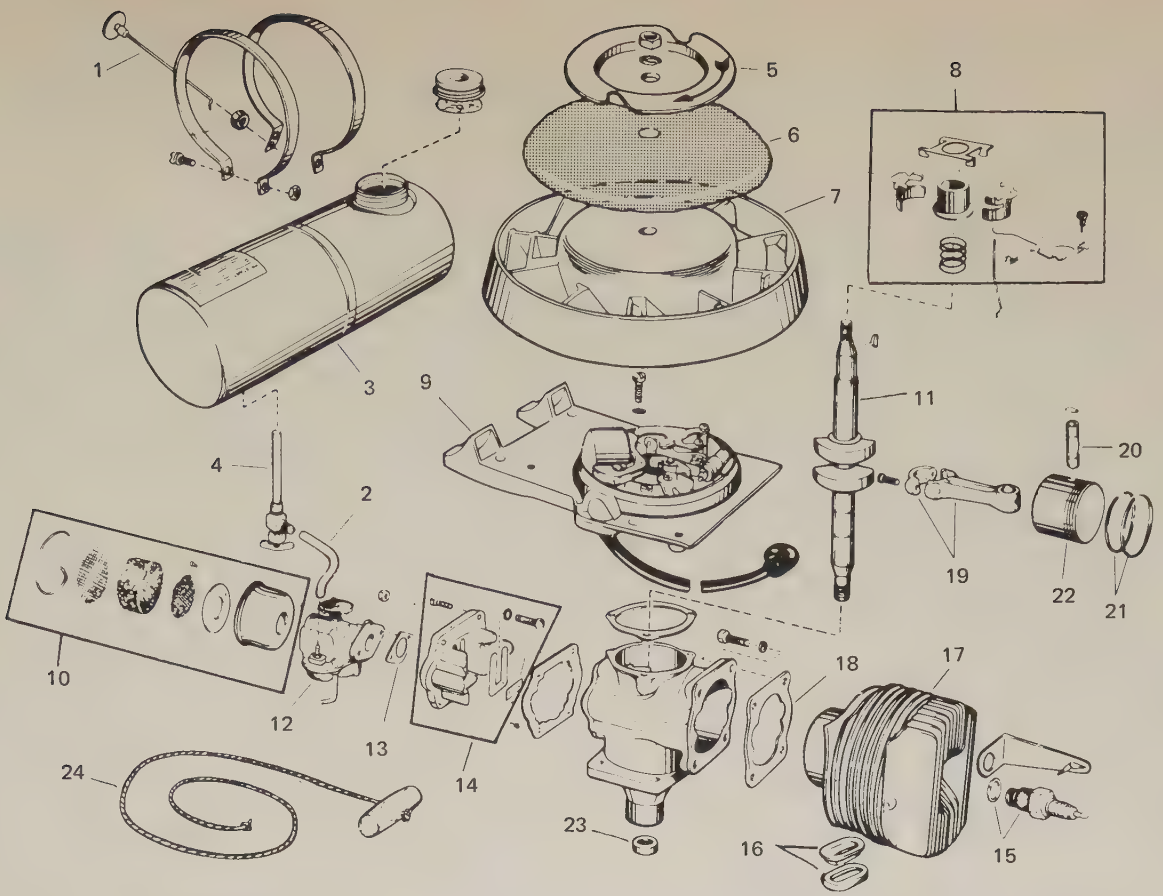


FIG. 9-19 A reed valve is used in the intake port of many two-cycle engines.



1. CHOKE-KNOB ASSEMBLY
2. GAS LINE
3. GAS-TANK ASSEMBLY
4. SHUT-OFF VALVE AND SCREEN ASSEMBLY
5. STARTER PULLEY
6. FLYWHEEL SCREEN
7. FLYWHEEL ASSEMBLY
8. GOVERNOR ASSEMBLY
9. MAGNETO ASSEMBLY
10. AIR-FILTER ASSEMBLY
11. CRANKSHAFT
12. CARBURETOR ASSEMBLY
13. CARBURETOR GASKET
14. REED-VALVE ASSEMBLY
15. SPARK PLUG
16. EXHAUST SLEEVE
17. CYLINDER AND SLEEVE ASSEMBLY
18. GASKET
19. CONNECTING-ROD ASSEMBLY
20. CONNECTING-ROD PIN
21. PISTON RINGS
22. PISTON
23. CRANKCASE
24. STARTER ROPE

FIG. 9-20 Disassembled view of a one-cylinder air-cooled engine used on a power lawn mower. *(Lawn Boy Division of Outboard Marine Corporation)*

port into the crankcase. At the same time, the piston has closed off the exhaust port and the transfer port, as you can see in Fig. 9-15. This traps the air-fuel mixture that already is in the combustion chamber. As the piston moves up, this air-fuel mixture is compressed.

As the piston nears TDC, ignition takes place (Fig. 9-16). The high combustion pressures drive the piston down. The force applied through the connecting rod against the crankpin turns the crankshaft.

As the piston moves down the cylinder, the top of the piston moves below the exhaust port in the cylinder wall (Fig. 9-17). This opens the exhaust port. Burned gases, still under some pressures, begin to flow out of the cylinder through the exhaust port. In Fig. 9-17, notice that the piston also has closed the intake port into the crankcase.

As the piston nears BDC, the top edge of the piston moves below the transfer port, opening it (Fig. 9-18). Now the air-fuel mixture in the crankcase transfers to the cylinder by flowing through the open transfer port.

After the piston has passed through BDC and starts up again, it closes the transfer port and the exhaust port (Fig. 9-15). Now the fresh air-fuel charge above the piston is compressed and ignited. This same sequence of events takes place again and continues as long as the engine runs.

○ 9-12 CRANKCASE COMPRESSION In a two-cycle engine, the air-fuel mixture is delivered to the cylinder under pressure. This pressure is applied to the air-fuel mixture in the crankcase. (The crankcase is the lower part of the engine which contains the crankshaft.) In many engines, the crankcase is sealed except for a reed (or leaf) valve located in the intake port (Fig. 9-19). The reed valve is a flexible, flat metal plate that fits between the carburetor and the intake port.

There are holes under the reed valve that connect it with the carburetor. Figure 9-19 shows the arrangement in which the reed valve is mounted on the side

of the crankcase, just outside the intake port. When the piston is moving up, a partial vacuum is produced in the sealed crankcase. Atmospheric pressure lifts the reed valve off the holes and pushes air-fuel mixture into the crankcase (Fig. 9-19). After the piston passes TDC and starts down again, pressure begins to build up in the crankcase. This pressure closes the reed valve so that further downward movement of the piston compresses the trapped air-fuel mixture in the crankcase. The pressure which is built up on the air-fuel mixture then causes it to flow up through the transfer port into the cylinder when the piston moves down enough to clear the transfer port (Fig. 9-19).

A disassembled view of a two-cycle engine is shown in Fig. 9-20. Study this illustration carefully. Identify the reed-valve assembly, cylinder, piston, connecting rod, and other parts. This is an air-cooled engine. Notice that the cylinder and head have metal fins to help carry away excess heat and prevent overheating of the engine.

This engine, installed in a lawn mower, is shown in cutaway view in Fig. 9-21. Note that the cylinder is placed horizontally (to the left in the illustration) and that the carburetor is on the opposite side of the crankshaft (to the right in the illustration). A later chapter describes the fuel system.

○ 9-13 CRANKCASE PRESSURE IN MULTIPLE-CYLINDER ENGINES In multiple-cylinder engines, each cylinder must have its own individual sealed crankcase. Therefore, on a two-cylinder two-cycle engine, the crankcase is divided into two separate sealed compartments. Each compartment provides primary compression of the air-fuel mixture for the piston-cylinder combination directly above it. Figure 9-22 shows a two-cylinder two-cycle engine. Notice how the crankcase for each cylinder is sealed from the others.

○ 9-14 ENGINE CONSTRUCTION Some engines use other kinds of valves than the reed valve. Also, all engines have some sort of flywheel. And engines must be provided with some means of getting rid of excess heat. This means that all engines must have some sort of cooling system. In the following chapter, which discusses various types of small engines and the details of their construction, we describe these features.

REVIEW QUESTIONS

1. What is the difference between an internal-combustion engine and an external-combustion engine?
2. How many cylinders does a "small engine" have?
3. What provides the seal between the piston and the cylinder wall?
4. Why don't the piston rings wear out quickly as they slide up and down the cylinder walls?
5. How many rings are there on a two-cycle engine piston?

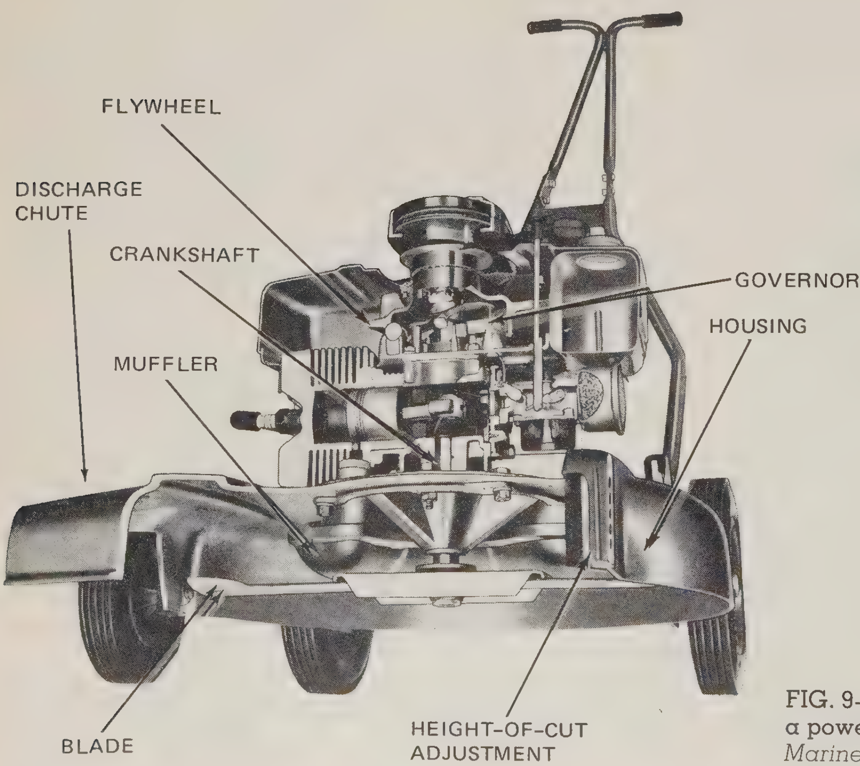


FIG. 9-21 Cutaway view of a two-cycle engine used in a power lawn mower. *(Lawn Boy Division of Outboard Marine Corporation)*

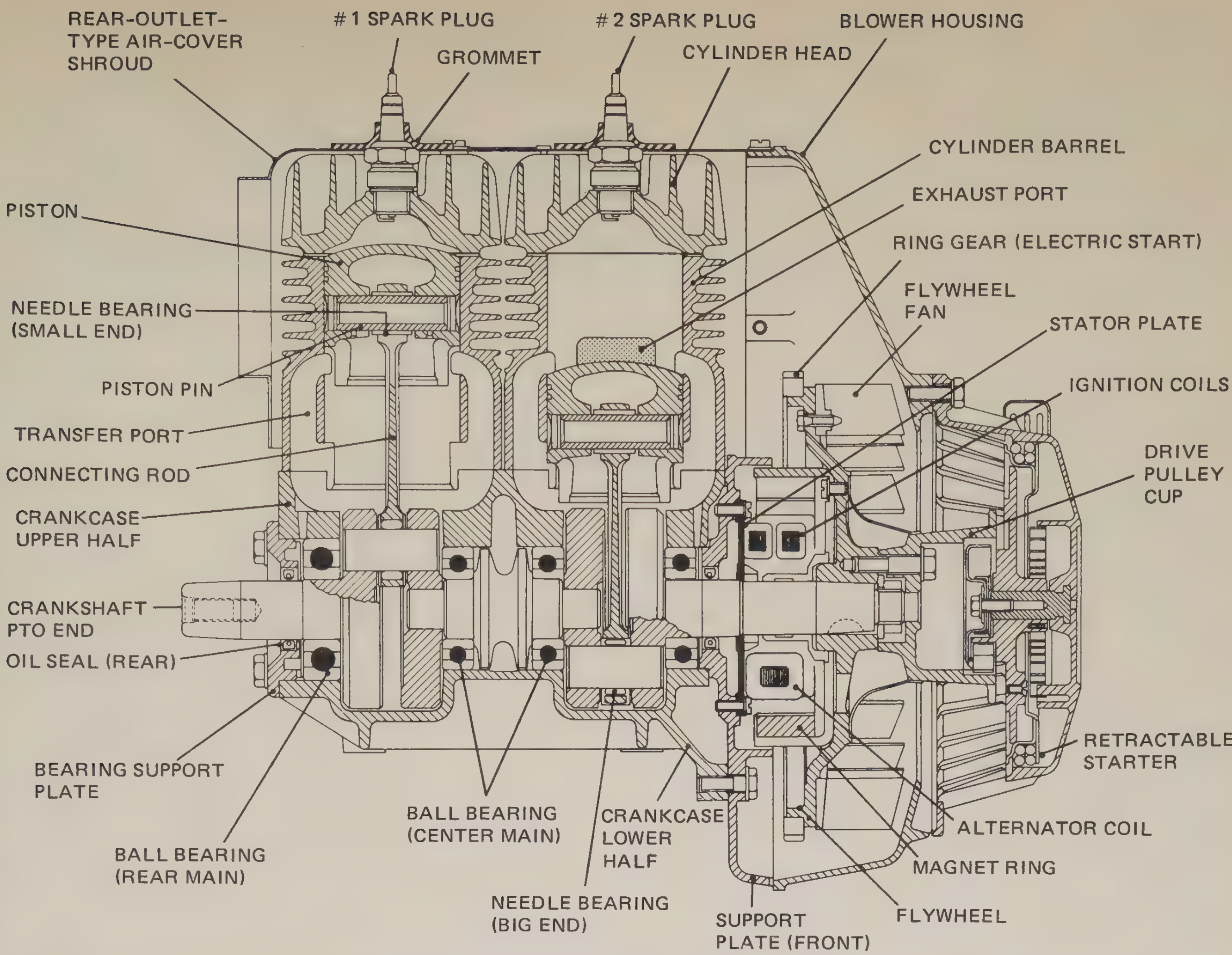


FIG. 9-22 In a two-cycle engine with more than one cylinder, such as this two-cycle two-cylinder engine, each of the cylinders must have its own sealed crankcase. The sealed ball bearings placed between the cranks of the crankshaft, as shown, provide this seal. *(Kohler Company)*

6. What is the difference between reciprocating and rotary motion?

7. In the engine, what changes the reciprocating motion of the piston into rotary motion?

8. What two types of bearings are used in engines?

9. Why are sleeve bearings used so often in small engines?

10. What is a piston stroke?

11. What are the three ports required by a two-cycle engine?

12. Where does the intake port lead?

13. What opens and closes the ports in the two-cycle engines discussed in this chapter?

14. What is crankcase compression?

15. Where is the reed valve located?

16. Why does a multicylinder two-cycle engine have a sealed crankcase for each cylinder?

SELF PROJECTS

1. To understand the operation of the two-cycle engine, you must understand the action of the ports. Look at an assortment of two-cycle engine cylinders. Identify each of the ports. On a sheet of paper for your notebook, write down the make of cylinder and its size. Then locate the intake port. If there is no mounting for the carburetor, you know that the cylinder is from a rotary-valve engine. Write down that fact.

   Next, locate the transfer ports in the cylinder wall. Probably there will be more than one transfer port. Count the number of transfer-port holes, and write that down. Look for any bridges

or other special design features to prevent the piston rings from hanging in the transfer ports and breaking. Then examine the exhaust port. It probably will be the port that comes closest to the top of the cylinder. Carbon deposits in the port is another indication that you found the exhaust port.

2. On a sheet of paper for your notebook, make a rough sketch of the location and shape of the ports. Then identify and label each port in your sketch. As you do this for several two-cycle-engine cylinders, you will begin to see the great variety of port shapes and locations in two-cycle engines.

10 Chapter

Small-Two-Cycle-Engine Construction

After studying this chapter, you should be able to:

1. **Describe the construction of the two-cycle engine**
2. **List the various types of valves used in two-cycle engines**
3. **Explain why flywheels are necessary**

○ 10-1 ONE-CYLINDER TWO-CYCLE ENGINE CONSTRUCTION Figure 9-20 shows a disassembled one-cylinder two-cycle engine used in a power lawn mower. Figure 10-1 shows a similar engine assembled. Notice that this assembly includes the engine, a rope-rewind starter, and a cooling shroud for directing cooling air around the engine.

Figure 10-2 shows the cylinder and cylinder head removed from a similar engine. There is a difference between the engines in Figs. 10-1 and 10-2. This difference is that the engine in Figs. 9-20 and 10-1 has a one-piece head-and-cylinder assembly. There is no particular advantage to having a one-piece head-and-cylinder assembly or to having the head and cylinder separate. Different engine manufacturers have different ways of manufacturing engines. Figure 10-3 shows all of the parts, in exploded view, of an engine having a separate cylinder and cylinder head.

○ 10-2 OTHER TYPES OF VALVES In ○ 9-12, we described the reed valve. It is one of three devices used to control the timing and amount of air-fuel mixture that enters the crankcase while the intake port is open. Other devices include transfer ports that use the piston as a valve, described in ○ 9-11, and rotary valves. Figure 10-4 compares the construction of engines using these three means of controlling the valves (more frequently called *ports*) in two-cycle engines.

In Fig. 10-4*a*, a reed valve is used. It is attached to the crankcase, and opens and closes the intake port from the carburetor into the crankcase. Notice the location of the carburetor on the bottom of the crankcase. When you see an engine with the carburetor mounted on the crankcase, the engine is a two-cycle engine that probably uses a reed valve.

○ 10-3 ROTARY VALVES To improve the intake of the air-fuel mixture into the crankcase, some engines use a rotating disk valve, or rotary valve. Figure 10-4*c*

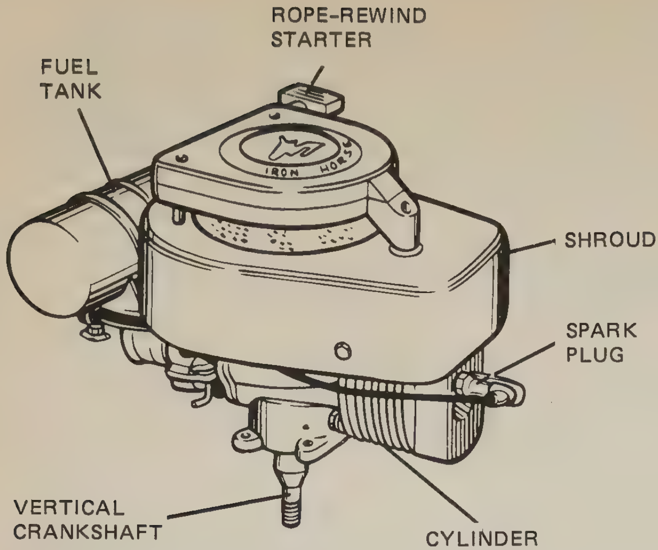


FIG. 10-1 Single-cylinder two-cycle engine removed from lawn mower. *(Lawn Boy Division of Outboard Marine Corporation)*

shows the disk and its location in the crankcase. Figure 10-5 is another view of a rotary valve. The intake port is in the crankcase wall and not in the cylinder wall. Rotation of the valve either closes the intake port or, when the notch in the valve is passing it, opens it.

Figures 10-6 and 10-7 show the positions of the rotary valve when the port is open and when it has just been closed. Notice that from the time the port just starts to open until it is just closed, the rotary valve has turned almost 180 degrees. The air-fuel mixture can flow into the crankcase for nearly half a crankshaft revolution. This is much more time than the transfer port controlled by the piston can provide (Fig. 10-4). With the transfer port, intake can take place only after the piston has moved up far enough to clear the intake port into the crankcase. Intake is cut off when the piston moves down past the intake port. This could provide as little as 90 degrees of crankshaft rotation, as contrasted with the 170 to 180 degrees of crankshaft rotation with the rotary valve.

○ 10-4 FLYWHEELS The power impulses resulting from the power strokes occur only during half a revolution of the crankshaft in two-cycle engines. As the piston passes TDC, the high pressure from the combustion of the air-fuel mixture pushes down on the piston. This push does not last long, however, because as the piston passes the exhaust port, the pressure is relieved. During the rest of the piston, connecting rod, and crankshaft motion, as the piston passes BDC and starts back up, there is no power being produced. It is only the momentum of the moving parts that carries the piston up to TDC so another power stroke can take place. Therefore, a single-cylinder engine has a tendency to speed up during the power stroke and slow down the rest of the time. To smooth out this speed-up and slow-down action, the engine is equipped with a flywheel.

The flywheel, as shown in Fig. 9-9, is mounted on the end of the crankshaft. Some engines have built-up crankshafts that include the flywheel inside the crankcase. A flywheel makes use of the property of inertia that all material things have. An object that is moving tends to keep moving. That is inertia. An object that is stationary tends to stay put. That also is inertia. So the flywheel, once it is set in motion, tends to keep moving. Then, when the engine tends to slow down during the nonpower part of the cycle, the flywheel helps to keep it moving. Also, when the power stroke occurs and the engine tends to speed up, the flywheel helps to keep it from suddenly speeding up. The flywheel gives up energy to keep the engine moving during the nonpower time and then stores energy when the engine tends to speed up.

○ 10-5 CRANKSHAFTS In most small engines the crankshaft is a single piece, as shown in Fig. 10-8. In other engines, the crankshaft is built up from several separate pieces. Figure 10-9 is an example of a built-up crankshaft for a single-cylinder engine. Notice that the crankpin is inserted in holes in the two crankshaft halves. This arrangement permits the use of a roller bearing at the connecting rod big end. A

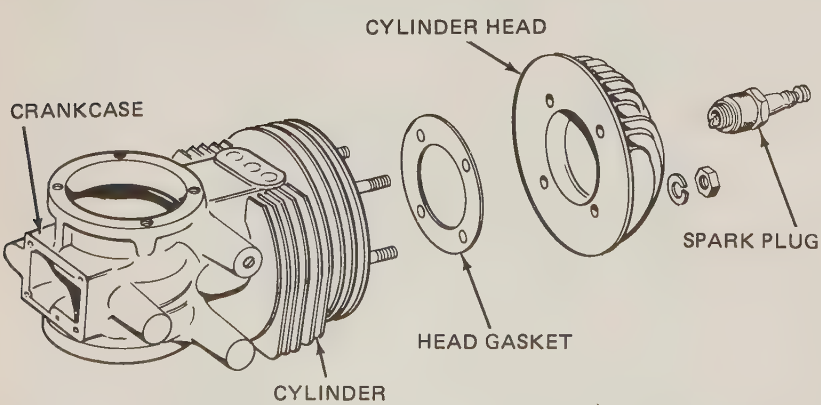


FIG. 10-2 Cylinder head and cylinder of a single-cylinder two-cycle engine, with related parts. *(Jacobsen Manufacturing Company)*

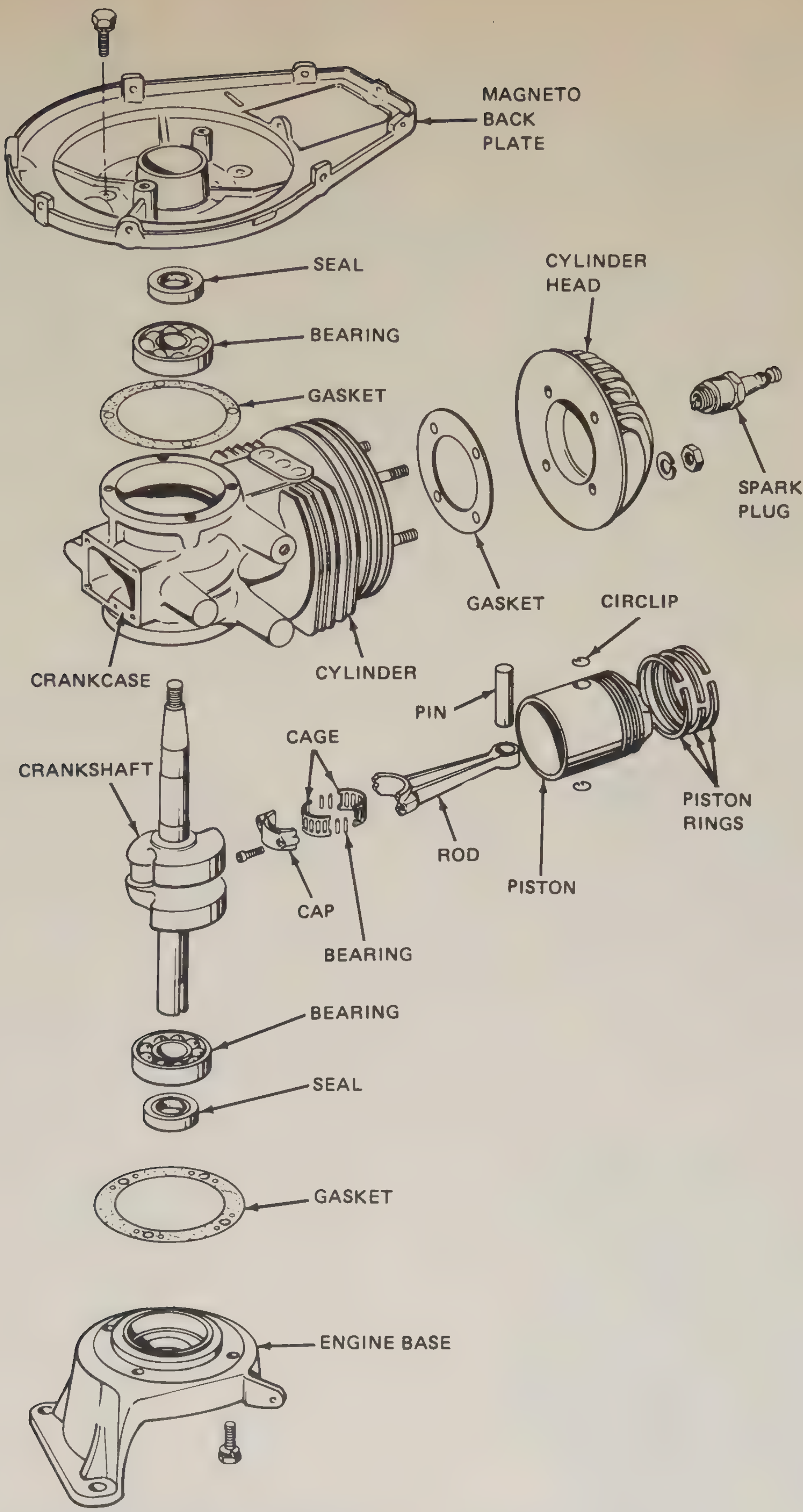


FIG. 10-3 Completely disassembled view of a single-cylinder two-cycle engine. *(Jacobsen Manufacturing Company)*

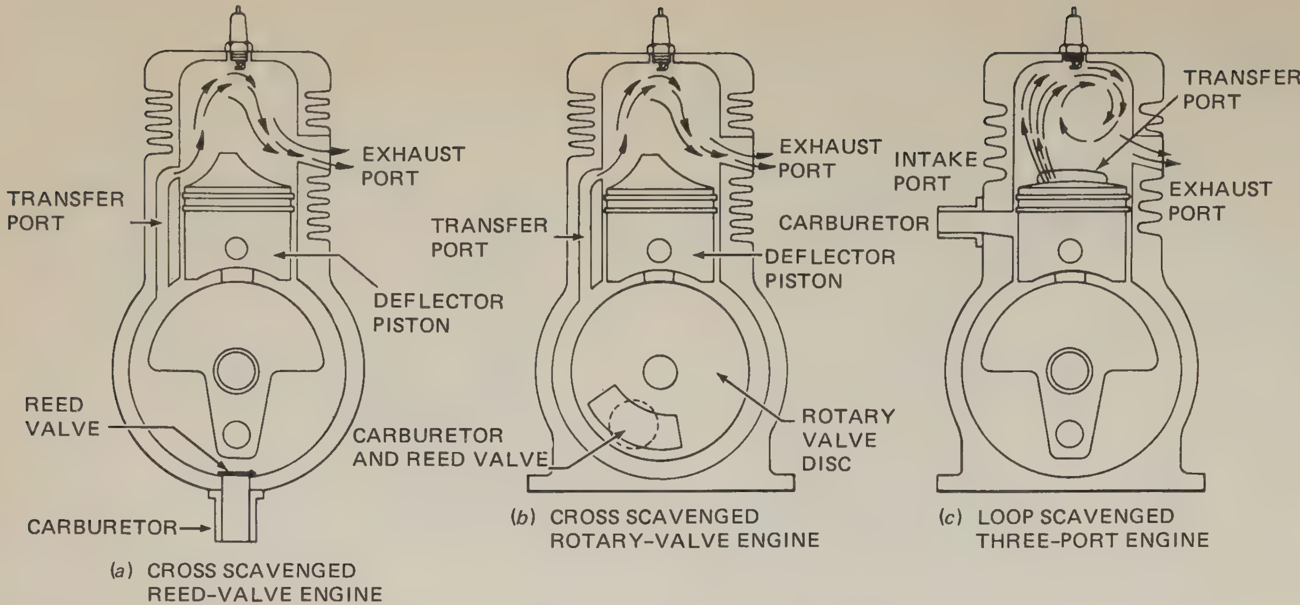


FIG. 10-4 Various ways of scavenging and valving a two-cycle engine. *(Kohler Company)*

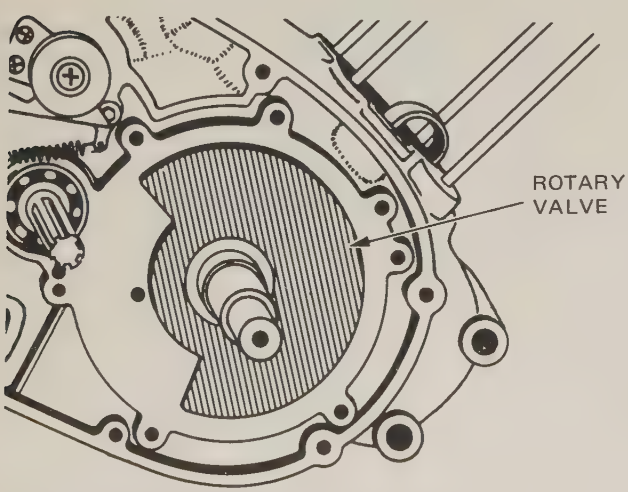


FIG. 10-5 Carburetor and side cover removed from engine to show rotary disk valve.

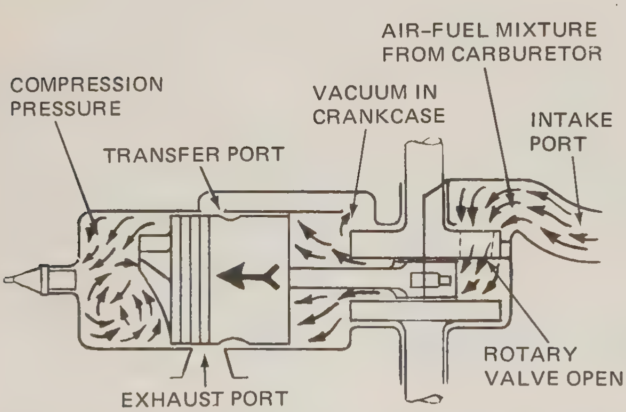


FIG. 10-6 As the crankshaft rotates, the valve port in the crankshaft lines up with the inlet port in the crankcase to admit the air-fuel mixture to the crankcase.

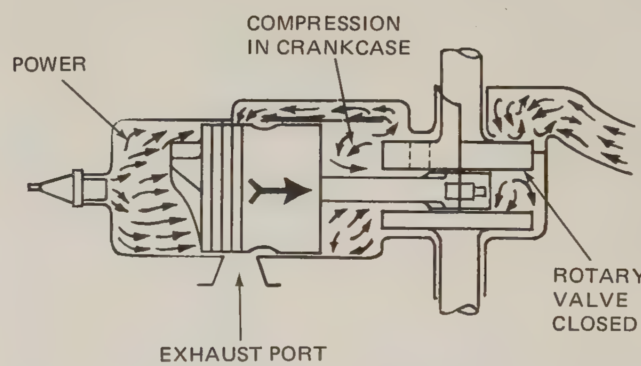


FIG. 10-7 Further rotation of the crankshaft moves the space in the rotary valve past the intake port, so that no air-fuel mixture can enter the crankcase.

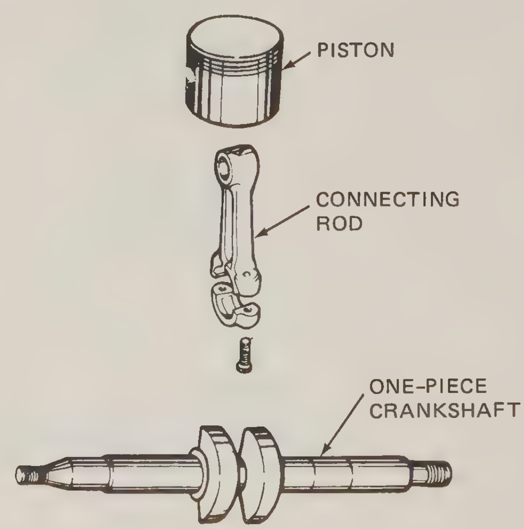


FIG. 10-8 Crankshaft, connecting rod, and piston from a single-cylinder engine.

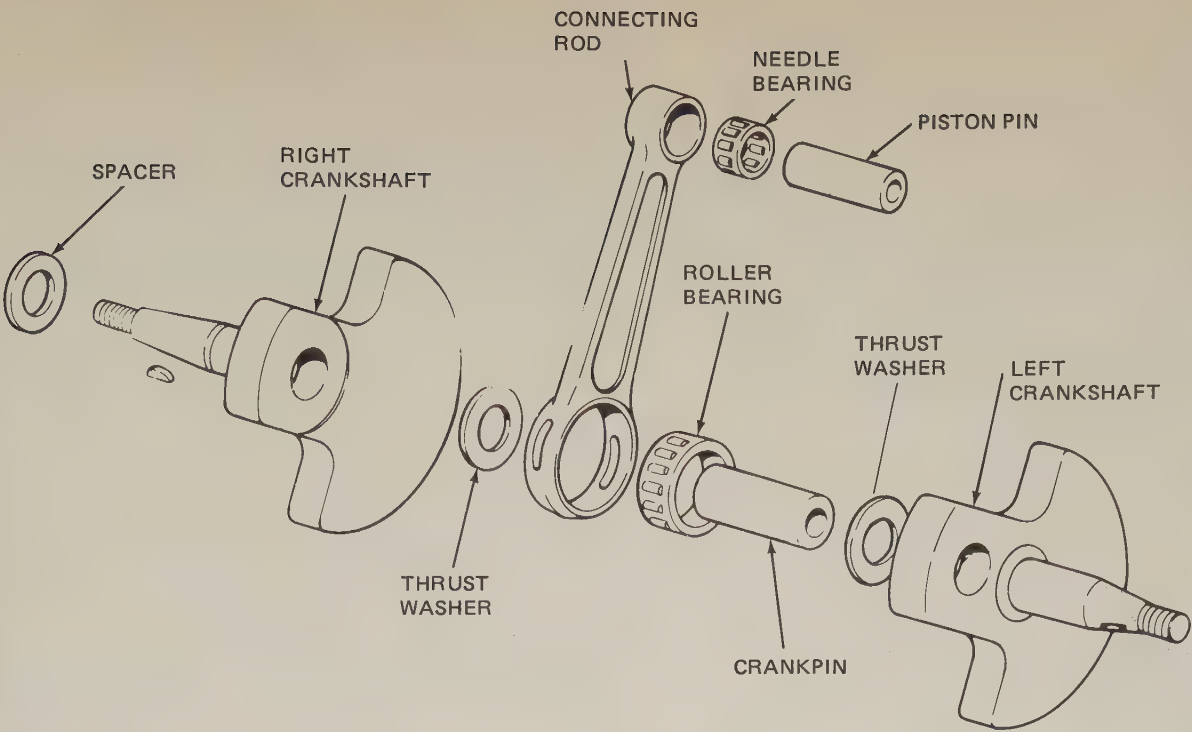


FIG. 10-9 Disassembled view of a built-up crankshaft for a single-cylinder engine. *(Harley-Davidson Motor Company, Inc.)*

roller bearing also is used at the piston pin. The piston-pin bearing has small rollers, almost needle size. Therefore, the bearing is called a needle bearing. Engine bearings are described in detail in ○ 9-7.

Multiple-cylinder two-cycle engines also may have built-up crankshafts. Many larger engines, and all automotive engines, use a one-piece crankshaft.

○ 10-6 ENGINE COOLING The combustion process in the engine cylinder produces a great deal of heat. Part of the heat is useful. It causes the push on the piston which makes the piston move and the crankshaft rotate. Part of the heat is lost in the hot exhaust gases. Some of the heat passes into the cylinder wall, cylinder head, and piston. This heat must be disposed of to prevent the cylinder walls, head, and piston from getting too hot. Excessive temperature will cause the oil film on the cylinder wall to fail. Without adequate means of disposing of the excess heat, the oil would char or burn and its lubricating properties would be lost. The result would be engine failure.

But even before seizure occurred, there could be serious difficulty in the engine. As the heat accumulated and the cylinder-head and spark-plug temperature went up, there would soon be a point at which preignition would occur. The spark plug would be so hot that it would ignite the air-fuel mixture prematurely. This condition could also cause engine failure, because preignition can melt holes in pistons and cause other internal damage.

To prevent such troubles, there has to be some means of getting rid of the excess heat of the cylinder walls, head, and piston. Two different means of doing this are used. One method uses air to carry away the heat. The other uses a liquid, such as water. In the method using air cooling, the cylinder walls and head have fins, as shown in Fig. 10-10. These fins are

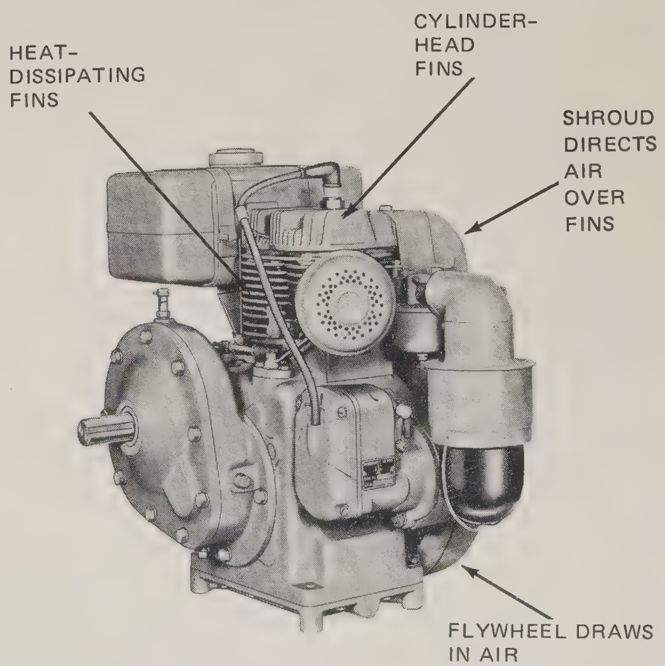


FIG. 10-10 Single-cylinder air-cooled engine showing fins in the cylinder and cylinder head. Note the shrouds that direct air over the fins. *(Wisconsin Motor Corporation)*

actually part of the head and cylinder. They greatly increase the outer metal surfaces and the area from which heat can escape into the surrounding air. To assist in this heat escape, many engines have shrouds and an air fan which forces air over and around the fins as shown in Fig. 10-11. The shroud is simply a metal sheet shaped to fit around the cylinder in such a way as to force the air to flow close to the fins. The air fan is built into the engine flywheel. The engine is cooled by the flow of air around the fins and is therefore called an air-cooled engine. Practically all single-cylinder engines are air-cooled. Some multiple-cylinder engines are also air-cooled.

The second method of cooling the engine uses a liquid, such as water, mixed with an antifreeze. In the liquid-cooled engine, the liquid is circulated in jackets, or pockets, that surround the cylinder walls and cylinder head. Most multiple-cylinder engines, particularly those used in automobiles, are of the liquid-cooled type. Chapter 9 covers liquid-cooling systems in detail.

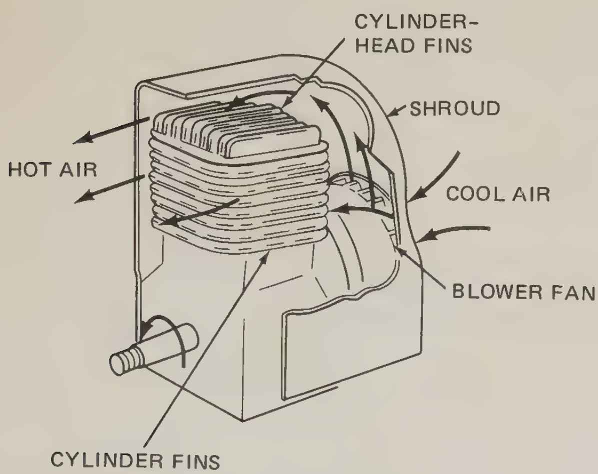


FIG. 10-11 Circulation of air around the cylinder cooling fins.

REVIEW QUESTIONS

1. What is the difference between an engine with a separate cylinder head and an engine that has a one-piece head-and-cylinder assembly?
2. What are three methods of controlling the intake port in a two-cycle engine?
3. What operates the reed valve?
4. What operates the rotary valve?
5. What type of engine has the carburetor located on the crankcase?
6. Name two types of crankshafts.
7. What two methods of cooling are used in small engines?

SELF PROJECT

Locate several disassembled two-cycle engines and examine their construction closely. Compare an engine with a separate cylinder and head to an engine that uses a single-piece cylinder-and-head assembly. Identify the ports and trace the passages for each port. Determine the type of intake-port control used in each engine. Study the crankshaft to determine if it is a single-piece crankshaft or a built-up crankshaft. Compare the connecting rod and bearings used with each type of crankshaft.

11
Chapter

Four-Cycle-Engine Operation

After studying this chapter, you should be able to:

1. **Explain the various ways in which small engines are classified**
2. **List the four strokes of the four-stroke cycle and describe each**
3. **Describe the valves and explain how they are operated**
4. **Define "volumetric efficiency"**
5. **Discuss the need for automatic compression release**
6. **Explain the differences between a two-cycle engine and a four-cycle engine**
7. **Identify correctly each type of engine**

○ 11-1 COMPARING THE TWO-CYCLE AND FOUR-CYCLE ENGINES The four-cycle engine is very similar in many ways to the two-cycle engine. In both engines, a piston moves up and down in the cylinder. The piston is attached to a crank on the crankshaft by a connecting rod. When ignition of the compressed air-fuel mixture takes place, the high pressure drives the piston down. This push, carried through the connecting rod, causes the crankshaft to rotate.

To this point, the actions are similar in both engines. However, in the two-cycle engine, the air-fuel mixture is admitted to the cylinder, and the burned gases exit from the cylinder, through openings, or ports, in the cylinder wall. This action is shown in Figs. 9-15 to 9-18. Also in the two-cycle engine, air-fuel mixture is compressed in the cylinder every time the piston moves up. Every time the piston nears TDC, there is combustion and a resulting high pressure which pushes the piston down. Only two piston strokes are required to complete the cycle of engine operation in the two-cycle engine. Actually, the proper name is "two-stroke-cycle engine," because there are two piston strokes in the cycle. The proper name of the four-cycle engine is "four-stroke-cycle engine," because it takes four piston strokes to complete the cycle.

The four-cycle engine does not have ports in the cylinder wall. Instead, this engine has two openings at the top of the cylinder. These openings are plugged part of the time by movable metal plugs called valves. Figure 11-1 shows typical valves for a four-cycle engine. These valves are operated by a camshaft driven by gears in many engines. Other engines use a chain and sprockets, as we explain later.

The valves move up and down in valve guides in the cylinder block (or in some engines, in the cylinder head). One of the valves operates to allow air-fuel mixture to enter the cylinder. This is the intake valve. The other valve operates to allow the burned gases to escape from the cylinder. This is the exhaust valve.

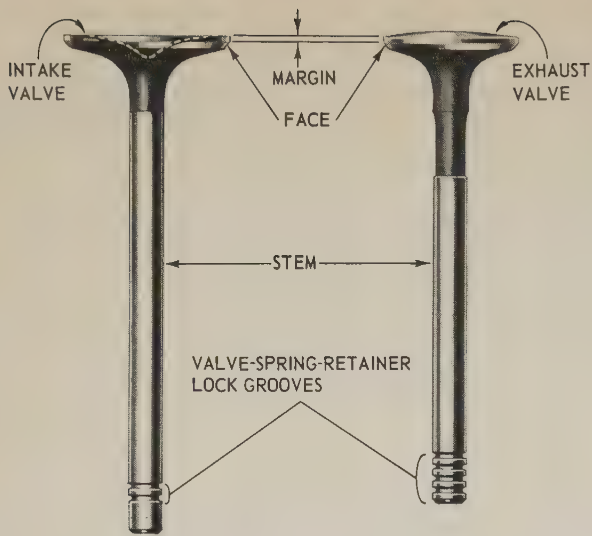


FIG. 11-1 Typical engine valves. *(Chrysler Corporation)*

In Fig. 11-1 (and in many engines) the intake valve is larger than the exhaust valve. The intake valve is larger because the only pressure pushing the air-fuel mixture into the cylinder, when the intake valve is open, is atmospheric pressure. But when the exhaust valve is open, there is a much higher pressure on the exhaust gases. Therefore, a smaller exhaust valve is satisfactory. The space in the cylinder block or head for valves is limited. The valve sizes and location must be selected to make the engine as efficient as possible.

○ 11-2 OPERATING THE VALVES

Figure 11-2 shows a typical arrangement for operating a valve in a small engine. The valve moves up and down in a valve guide which is part of the cylinder block. There is a valve spring that puts tension on the valve and tries to keep the valve closed or seated on the valve seat in the cylinder block. The valve spring is held between the cylinder block and a spring retainer. The spring retainer is attached to the valve stem by a retainer lock which fits into grooves in the valve stem. Below the valve stem is a valve lifter, or valve tappet, as it also is called. The valve lifter moves up and down in a bore, or hole, in the cylinder block.

The valve lifter rests on a cam which has one high spot, or lobe. The cam rotates as the crankshaft rotates. The two are geared together. Figure 11-3 shows a gearing arrangement for a small four-cycle engine. As the camshaft rotates, the cam lobe moves around under the valve lifter, causing it to be pushed upward, as shown in Fig. 11-4. This upward push overcomes the valve-spring tension so that the valve is raised off the valve seat. The valve is then open, and gas can pass through the opening between the valve seat and valve. If the valve is the intake valve, it is the air-fuel mixture from the carburetor that passes through the valve opening on its way to the cylinder.

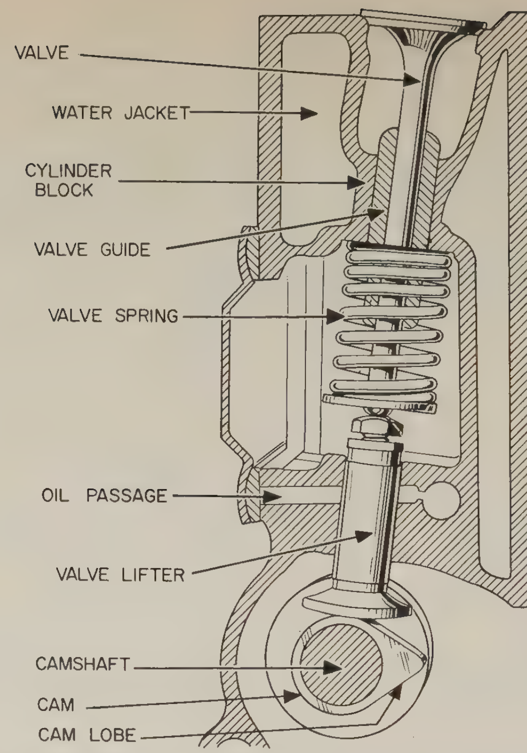


FIG. 11-2 Valve mechanism used in an L-head engine. The valve is raised up off its seat with every camshaft rotation.

If it is the exhaust valve that opens, then it is the exhaust gases (the gases left after the air-fuel mixture has burned) which pass through the valve opening on their way out from the engine cylinder.

Then, as the piston continues its movement and the crankshaft continues to rotate, the gears on the crankshaft rotate the camshaft. The lobe on the cam moves out of the way of the valve lifter. Now the spring on the valve forces the valve to close so the opening is sealed off, as shown in Fig. 11-5.

Notice that the gear on the camshaft is twice as large as the gear on the crankshaft. There is a reason for this. The camshaft must rotate at half the speed of the crankshaft. This makes the camshaft rotate only once for every two times the crankshaft turns. We will explain why this is necessary later.

○ 11-3 ENGINE OPERATION

Now let us take a closer look at the operation of the four-stroke-cycle engine. Figures 11-6 to 11-9 illustrate these four strokes. To start with, the intake valve has been pushed up off its seat by a cam lobe on the rotating camshaft as the piston is moving down. A mixture of air and fuel is being taken into the cylinder, flowing past the intake valve. This is the intake stroke, shown in Fig. 11-6.

Then, as the piston passes BDC, the intake valve closes. Now the piston starts up on the compression stroke, compressing the air-fuel mixture into the top of the cylinder. This is shown in Fig. 11-7.

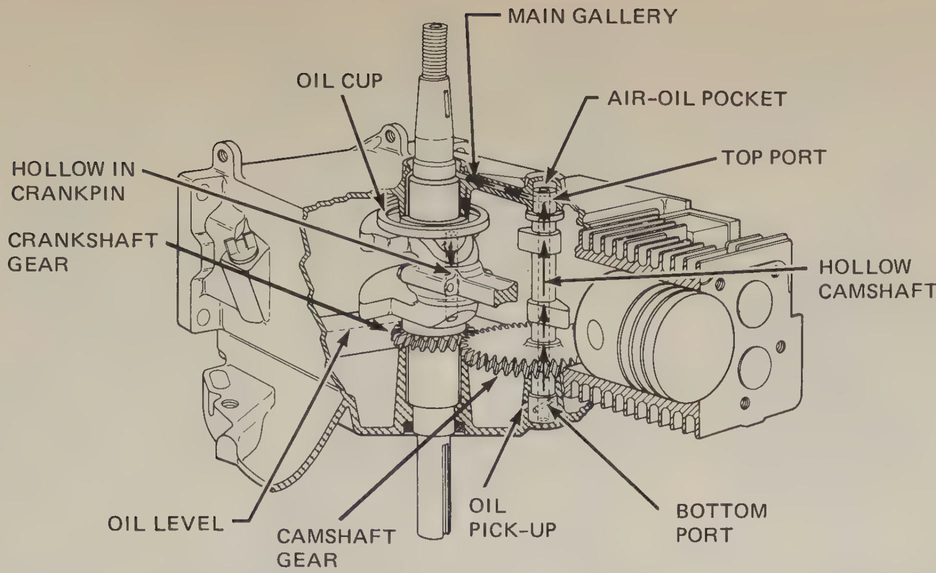


FIG. 11-3 Gearing arrangement in a small four-cycle horizontal engine for driving the camshaft from the crankshaft. This illustration also shows the flow of lubricating oil to the camshaft, crankshaft, and connecting-rod bearings. *(Kohler Company)*

Next, as the piston nears TDC on the compression stroke, an electric spark takes place at the spark plug. This sets fire to, or ignites, the compressed air-fuel mixture. Combustion and a pressure rise result, forcing the piston downward on the power stroke. The downward push on the piston may total as much as 2000 pounds (1814 kg) in a small engine. This powerful push is carried through the connecting rod to a crank on the engine crankshaft (Fig. 11-8). The electric ignition system, which produces the spark at the spark plug, will be explained later.

Finally, the fourth stroke in the four-stroke cycle occurs. This is the exhaust stroke. As the piston nears BDC on the power stroke, the exhaust valve opens. Now, as the piston moves up on the exhaust stroke, the burned gases in the cylinder are forced out, as shown in Fig. 11-9.

As the piston nears TDC on the exhaust stroke, the intake valve opens. Then, after TDC, the exhaust valve closes, and the whole cycle of events is repeated once again. The cycle is repeated continuously as long as the engine runs.

A completely disassembled view of the engine illustrated in Figs. 11-6 to 11-9 is shown in Fig. 11-10. Study this picture and identify all the parts.

Here is why the gear on the camshaft has to be twice as large as the gear on the crankshaft, as shown in Figs. 11-3 and 11-5: Each valve must open once while the crankshaft is turning two times. This means that each valve is open for only one piston stroke. Since there are four piston strokes in a complete cycle, each valve is open only one-fourth of the total running time.

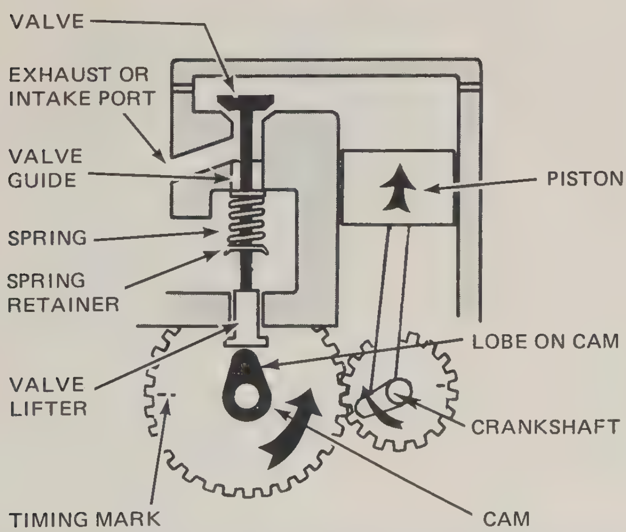


FIG. 11-4 As the camshaft is driven by the crankshaft, the cam lobe moves up under the valve lifter, and this forces the valve to move up off its seat.

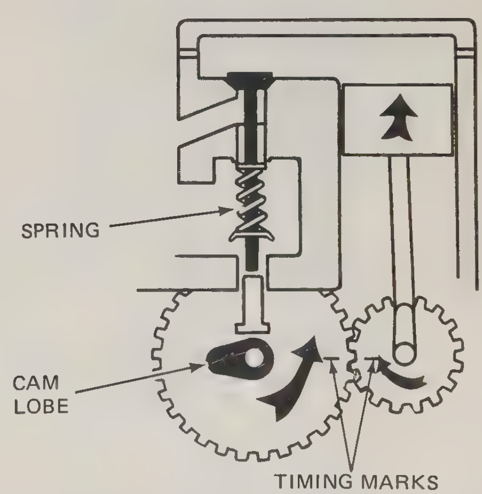


FIG. 11-5 Further rotation of the crankshaft and camshaft moves the lobe out from under the valve tappet, and this allows the spring to pull the valve down and reseat it.

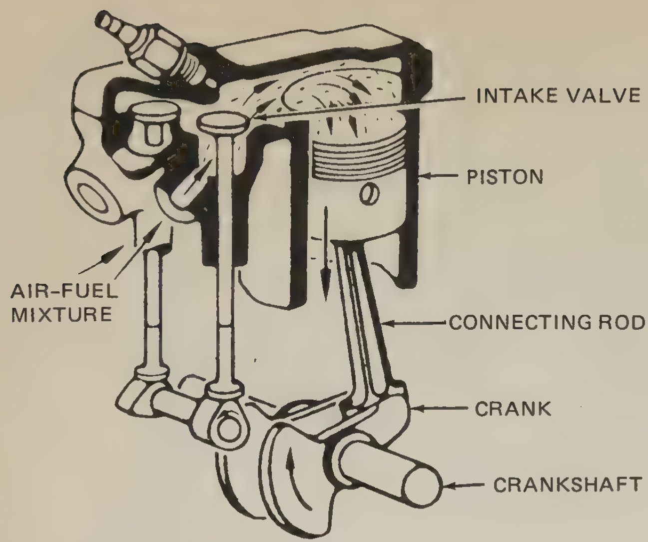


FIG. 11-6 The intake stroke of a four-cycle engine. The intake valve has closed and the piston is moving down, drawing the air-fuel mixture into the cylinder as shown. *(Clinton Engines Corporation)*

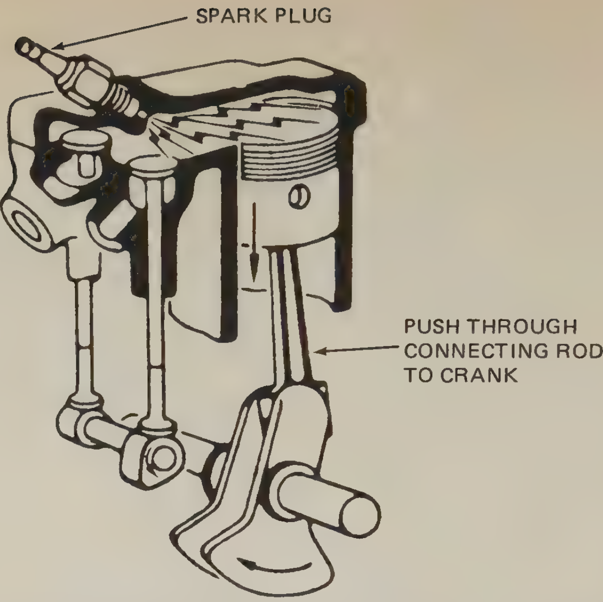


FIG. 11-8 Power stroke. The ignition system produces a spark at the spark plug that ignites the mixture. As it burns, the high pressure created pushes the piston down. *(Clinton Engines Corporation)*

○ 11-4 PISTON RINGS Two-cycle engines use one or two piston rings on the piston (○ 9-4), while the four-cycle engine uses three or more rings. The upper rings—the compression rings—work to hold the pressures in the combustion chamber. Oil is mixed with gasoline for the two-cycle engine, and this oil provides lubrication of the piston rings and piston.

In the small four-cycle engine, a different method of lubricating the cylinder wall, piston, and rings, is used. A supply of oil is kept in the bottom of the crankcase. This oil is splashed or pumped around so that droplets hit the cylinder wall and keep it oiled. At the same time, some of the droplets hit the valves and valve tappets, permitting them to move up and down easily on films of oil. The oil also covers the bearings in the engine so they are adequately lubricated. Figure 11-3 shows the lubrication system on one small four-cycle vertical-crankshaft engine.

While the four-cycle engine is running, a lot of oil splashes on the cylinder wall—so much that the two compression rings would pass too much of it. This oil could then work up into the combustion chamber, where it would be burned. The burned oil would leave carbon deposits that would soon clog the

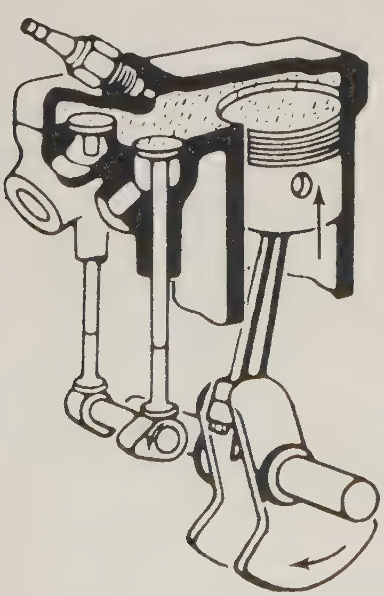


FIG. 11-7 Compression stroke. Both valves are closed, and the piston is moving upward, compressing the mixture. *(Clinton Engines Corporation)*

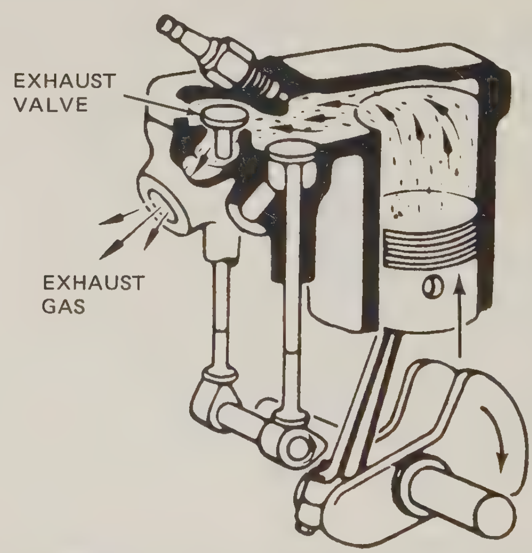
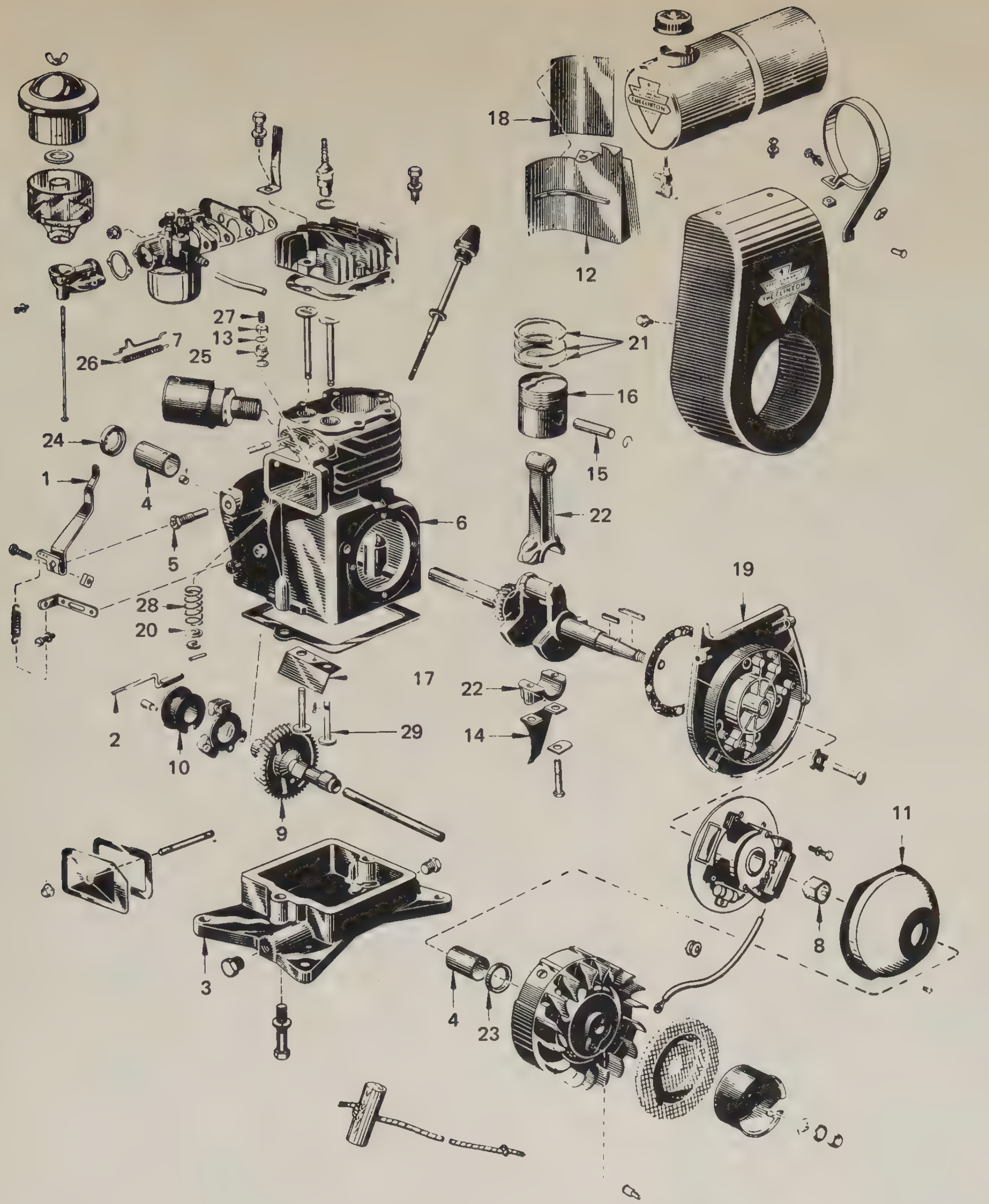


FIG. 11-9 Exhaust stroke. The exhaust valve has opened and the piston is moving upward, forcing the burned gases from the cylinder, as shown by the arrows. *(Clinton Engines Corporation)*



1. ARM—GOVERNOR THROTTLE—USED ON TYPE B
2. ARM AND WEIGHT ASSEMBLY—GOVERNOR
3. BASE—ENGINE
4. BEARING—MAIN (1-BEARING PLATE, 1-BLOCK)
5. BEARING—SHAFT, GOVERNOR THROTTLE
6. BLOCK ASSEMBLY—CYLINDER
7. BREATHER ASSEMBLY
8. CAM—BREAKER POINTS
9. CAMSHAFT
10. COLLAR ASEMBLY—GOVERNOR
11. COVER—DUST, BREAKER POINTS
12. DEFLECTOR—AIR
13. DISC—BREATHER
14. DISTRIBUTOR—OIL
15. PIN—WRIST
16. PISTON—STANDARD
17. PLATE—BAFFLE, CRANKCASE
18. PLATE—NAME, CLINTON ENGINES
19. PLATE—BEARING
20. RETAINER—VALVE SPRING
21. RING SET—STANDARD (3/16 OIL RING)
22. ROD ASSEMBLY—CONNECTING
23. SEAL—OIL (BEARING PLATE)
24. SEAL—OIL (CYLINDER BLOCK)
25. SEAT—BREATHER
26. SPRING—BACKLASH, GOVERNOR
27. SPRING—BREATHER HOLD DOWN
28. SPRING VALVE
29. TAPPET—VALVE

FIG. 11-10 Exploded view of a typical single-cylinder four-cycle air-cooled engine. Only the main parts are identified. *(Clinton Engines Corporation)*

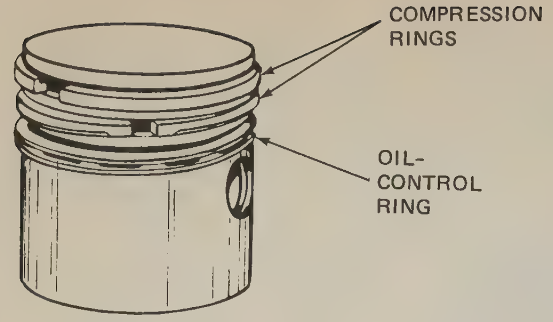


FIG. 11-11 A piston for a four-cycle engine. Note that it has three rings: two compression rings and one oil-control ring.

valves and spark plug, preventing them from working properly. The engine would begin to lose power. Soon it might stop working altogether. To prevent this, the piston on four-cycle engines is equipped with a third ring, called the oil-control ring, as shown in Fig. 11-11. Its purpose is to scrape excess oil off the cylinder walls on every downstroke of the piston. The oil drops back down into the crankcase instead of working its way up into the combustion chamber.

○ 11-5 ENGINE BEARINGS The various kinds of bearings used in small engines are described in ○ 9-7. You will find both the sliding and rolling types of bearings in small four-cycle engines. We will describe the method of lubricating bearings and the other moving parts in the engine in Chap. 15.

○ 11-6 FLYWHEELS Four-cycle engines require flywheels, which were described in ○ 10-4. Flywheels keep the engine running more smoothly. In small engines, they also may carry the magnets that are part of the magneto ignition system and part of the alternator that produces current to charge the battery. We will discuss these devices in following chapters.

○ 11-7 VALVE TIMING The valves open and close, not at TDC or at BDC, but sometime before or after the piston reaches the upper or lower limit of travel. There is a reason for this. The intake valve normally opens several degrees of crankshaft rotation before TDC on the exhaust stroke. That is before the exhaust stroke is finished. This gives the valve enough time to reach the fully open position before the intake stroke begins. Then, when the intake stroke starts, the intake valve is already wide open and air-fuel mixture can start to enter the cylinder immediately. The intake valve remains open for several degrees of crankshaft rotation after the piston has passed BDC at the end of the intake stroke. This allows additional time for the air-fuel mixture to continue to flow into the cylinder. The fact that the piston has already passed BDC and is moving up on the compression stroke while the intake valve is still open does not affect the movement of air-fuel mixture into the cylinder. Actually, air-fuel mixture is still flowing in as the intake valve starts to close.

The reason for this is that the air-fuel mixture has inertia. It tends to keep on flowing after it once starts through the carburetor and into the engine cylinder. The momentum of the mixture then keeps it flowing into the cylinder even though the piston has started up on the compression stroke. This packs more air-fuel mixture into the cylinder and results in a stronger power stroke. Volumetric efficiency (explained in Chap. 14) is improved.

For a somewhat similar reason, the exhaust valve opens before the piston reaches BDC on the power stroke. As the piston nears BDC, most of the push on the piston has ended. No power is lost by opening the exhaust valve toward the end of the power stroke. This gives the exhaust gases additional time to start leaving the cylinder so that exhaust is under way by the time the piston passes BDC and starts up on the exhaust stroke. The exhaust valve then stays open for several degrees of crankshaft rotation after the piston has passed TDC and the intake stroke has started. This makes good use of the momentum of the exhaust gases. They are moving rapidly toward the exhaust port. Leaving the exhaust valve open for a few degrees after the intake stroke starts gives the exhaust gases some additional time to leave the cylinder. This allows more air-fuel mixture to enter on the intake stroke so that a stronger power stroke results. Volumetric efficiency is improved.

Actual timing of the valves varies with different four-cycle engines. A typical example for a small engine is shown in Fig. 11-12. The intake valve opens 15 degrees of crankshaft rotation before TDC on the exhaust stroke, and it stays open until 50 degrees of

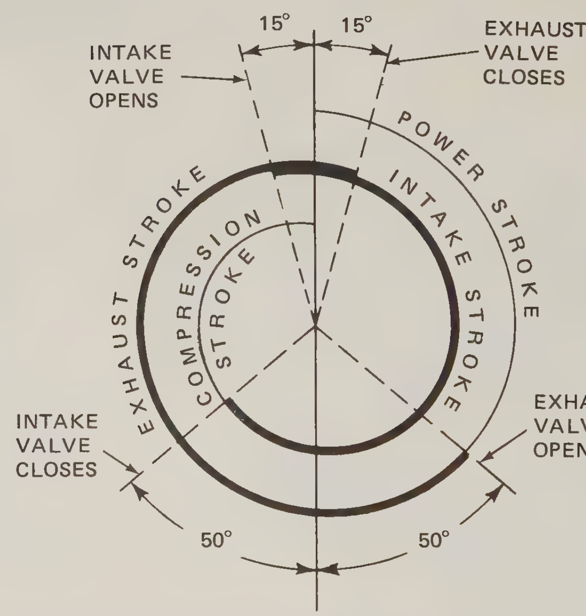


FIG. 11-12 Intake- and exhaust-valve timing in a typical small engine. The complete cycle of events is shown as a 720-degree spiral, which represents two complete crankshaft revolutions. The timing of valves differs for different engines.

crankshaft rotation after BDC on the compression stroke. The exhaust valve opens 50 degrees before BDC on the power stroke and stays open 15 degrees after TDC on the intake stroke. This gives the two valves an overlap of 30 degrees at the end of the exhaust stroke and beginning of the compression stroke.

○ 11-8 AUTOMATIC COMPRESSION RELEASE Cranking an engine is sometimes difficult. To pull the engine through the compression stroke requires some effort, either muscle power or starting-motor power. One way to reduce this effort is to partly release the compression pressure during cranking. One method of doing this is shown in Fig. 11-13. The mechanism consists of a pair of flyweights on the camshaft drive gear. When the engine is not running, the flyweights are held in their inner position by springs, as shown to the left in Fig. 11-13. In this position, a tang on the end of one of the flyweights has moved out of a notch in the base circle of the exhaust cam, as shown to the lower left. When the engine is cranked for starting, this tang prevents the exhaust valve from closing completely. Every time the base circle of the cam comes around under the valve tappet of the exhaust valve, it prevents the tappet from moving all the way down. With the exhaust valve held partly open, some of the compression pressure is relieved.

After the engine starts and engine speed increases, centrifugal force acting on the two flyweights forces them to move out into the running position, as shown to the right in Fig. 11-13. This movement allows the tang on the end of one of the flyweights to move into the notch in the base circle of the cam, as shown to the lower right in Fig. 11-13. When the base circle of the cam for the exhaust valve comes around under the valve tappet, the valve tappet can come all the way down. This allows the exhaust valve to close completely. Engine operation continues in a normal manner as long as the engine speed is maintained. However, if the engine is stopped, then the springs will cause the flyweights to move into the starting position, as shown to the left in Fig. 11-13, in readiness for another starting cycle.

○ 11-9 I-HEAD ENGINE The type of engine described above and shown in Figs. 11-2 to 11-10 is called an L-head engine. The cylinder and combustion chamber form the shape of an inverted L. Most small four-cycle engines are of this type. They have the valves located in the cylinder block. Some small four-cycle engines and almost all automotive engines are of the I-head, or overhead-valve, type. In this type of engine, the valves are located overhead, in the cylinder head. Figure 11-14 shows a cutaway view of this type of engine. Figure 11-15 shows the essential parts required to operate the valves. The I-head engine requires two more parts per valve than the L-head engine: push rods and rocker arms. The rocker arms are held in place on a shaft, or on ball studs. With either arrangement, the rocker arms are free to

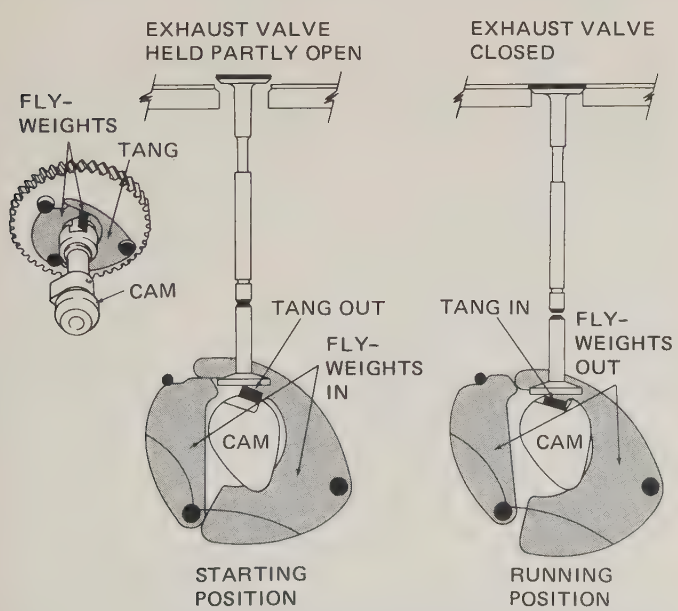


FIG. 11-13 Operation of the automatic compression release. *(Kohler Company)*

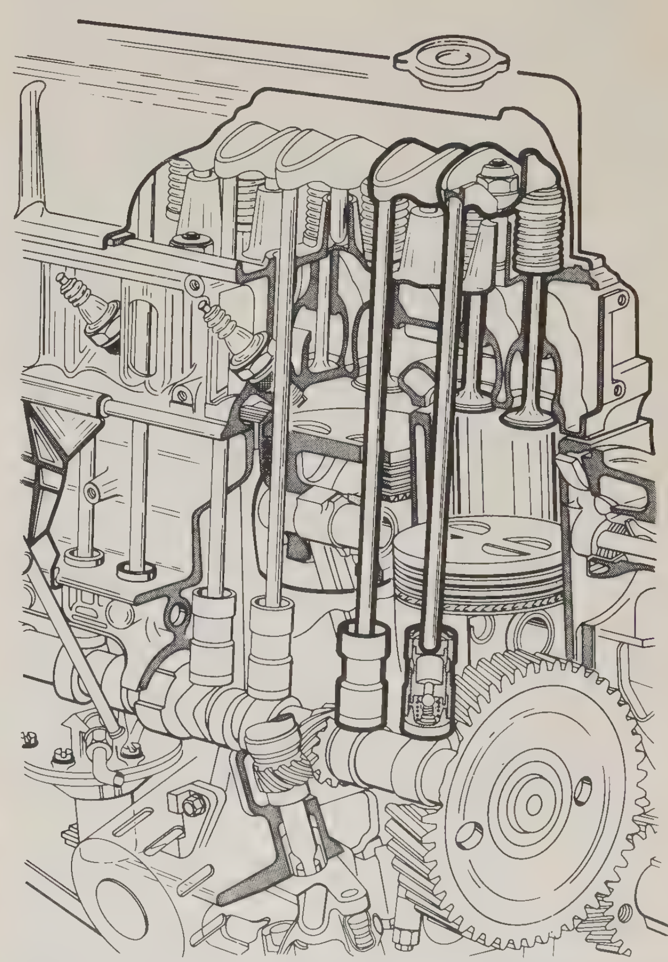


FIG. 11-14 Partial cutaway view of a four-cylinder in-line overhead-valve engine.

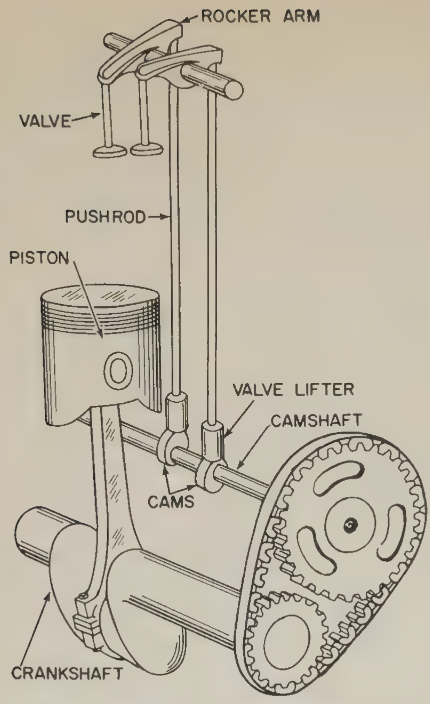


FIG. 11-15 Valve-operating mechanism for an I-head, or overhead-valve, engine.

rock up and down. When the cam lobe moves around under the valve lifter, the lifter is raised and this pushes up on the push rod. The push rod causes the rocker arm to rock so that the rocker arm pushes down on the end of the valve stem. As a result, the valve is pushed down off the valve seat and the valve opens. This type of engine often is called a push-rod engine. Most small engines are of the L-head type, because they are simpler in construction and easier to service. However, there are some small engines with the valves in the cylinder head.

○ 11-10 A COMPARISON OF TWO-CYCLE AND FOUR-CYCLE ENGINES It takes two revolutions of the crankshaft to complete the four strokes in a four-stroke-cycle engine. For the first half revolution, or for 180 degrees, the piston is moving down on the intake stroke. For the next half revolution, the piston is moving up on the compression stroke. For the third half revolution of the crankshaft, the piston is moving down on the power stroke. For the fourth half revolution, the piston is moving up on the exhaust stroke. Figures 11-6 to 11-9 show these four strokes.

Most larger internal-combustion engines and practically all automotive engines are of the four-stroke-cycle type. Every fourth piston stroke in each cylinder is a power stroke.

In the two-stroke-cycle engine, a power stroke occurs every two piston strokes. Every downward movement of the piston is a power stroke. In effect, the intake and compression strokes are combined. Also, the power and exhaust strokes are combined. We described how the two-cycle engine works in Chap. 9.

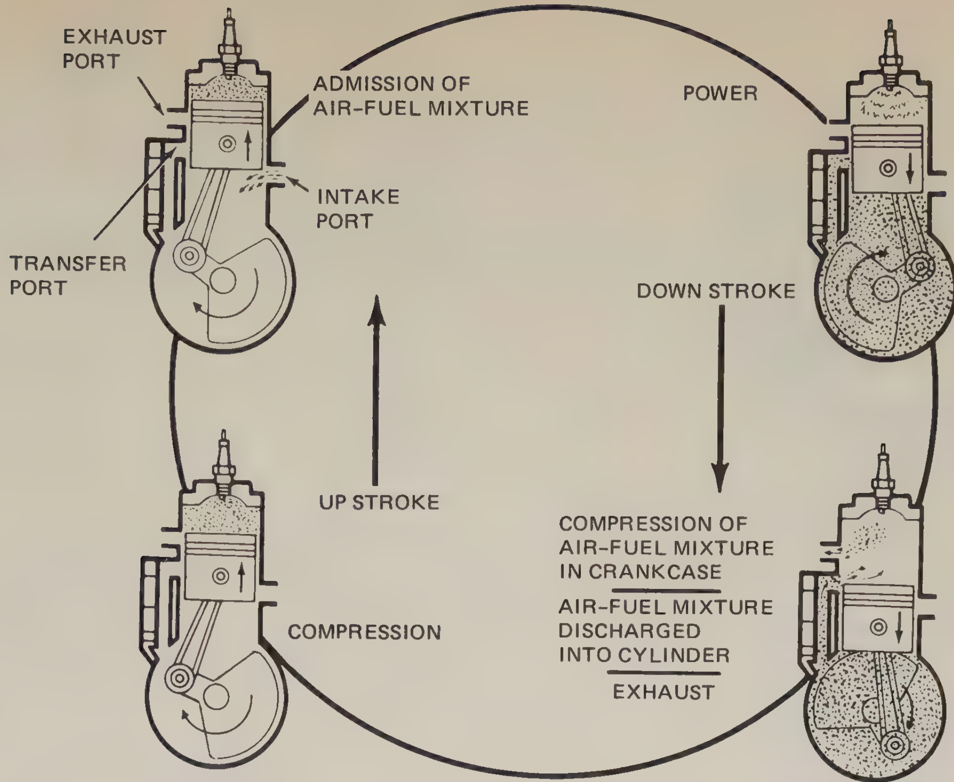
You might think that because the two-cycle engine has twice as many power strokes as a four-cycle engine (Fig. 11-16), it would produce twice as much horsepower as a four-cycle engine of the same size, running at the same speed. However, this is not true. In the two-cycle engine, when the intake and exhaust ports have been cleared by the piston, there is always some mixing of the fresh charge and the burned gases. Not all the burned gases get out, and this prevents a larger fresh charge from entering. Therefore, the power stroke that follows is not as powerful as it could be if all the burned gases were exhausted and a full charge of air-fuel mixture entered. In the four-cycle engine, nearly all the burned gases are forced from the combustion chamber by the upward-moving piston. A comparatively full charge of air-fuel mixture can enter, because a complete piston stroke is devoted to the intake of the mixture. This contrasts with only part of a stroke on the two-cycle engine. Therefore, the power stroke in the four-cycle engine produces more power.

○ 11-11 THE CRANKSHAFT OPERATING POSITION We have discussed various classifications of small engines: two-cycle and four-cycle, I-head and L-head, air-cooled and water-cooled. Small two-cycle engines can be classified in another way. This is by the operating position of the crankshaft. There are three basic crankshaft positions:

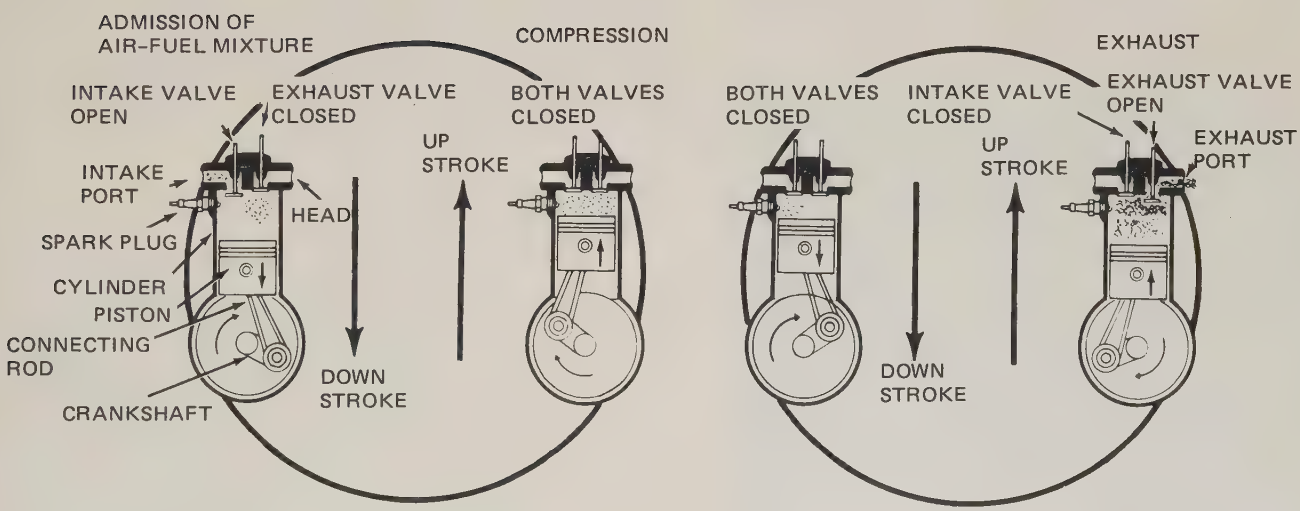
1. Vertical position, as shown in Fig. 9-21
2. Horizontal position, as shown in Fig. 11-17
3. Multiple positions, as required with a chain saw (Fig. 11-18)

○ 11-12 HOW TO TELL A TWO-CYCLE FROM A FOUR-CYCLE ENGINE The small-engine mechanic can usually tell at a glance whether an air-cooled engine is of the two-cycle or four-cycle type. The four-cycle engine has an oil sump and an oil-filler plug. The two-cycle engine does not. The four-cycle engine requires oil drains and refills periodically, just as automobiles do. In the two-cycle engine, the oil is added to the gasoline so that a mixture of gasoline and oil enters the crankcase with the air.

Another distinguishing feature is that in the four-cycle engine, the muffler is installed at the head end of the cylinder close to the exhaust-valve location. You can see the muffler location in Fig. 11-17. The muffler on the two-cycle engine is installed toward the middle of the cylinder, at the exhaust-port location. Notice the location of the muffler on the power-lawn-mower engine shown in Fig. 9-21.



TWO STROKES—ONE REVOLUTION



FOUR STROKES—TWO REVOLUTIONS

FIG. 11-16 Comparison of two-stroke-cycle and four-stroke-cycle engines. The two-stroke-cycle engine is of the piston-port type. The four-stroke-cycle engine is of the I-head type.

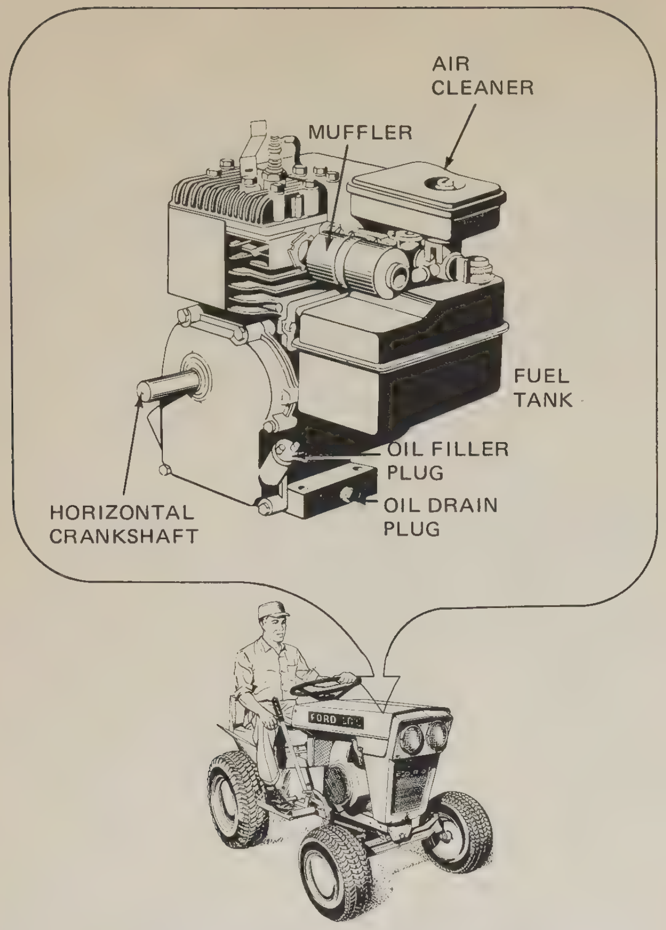


FIG. 11-17 Some small engines have a horizontal crankshaft such as this one used in a riding mower.

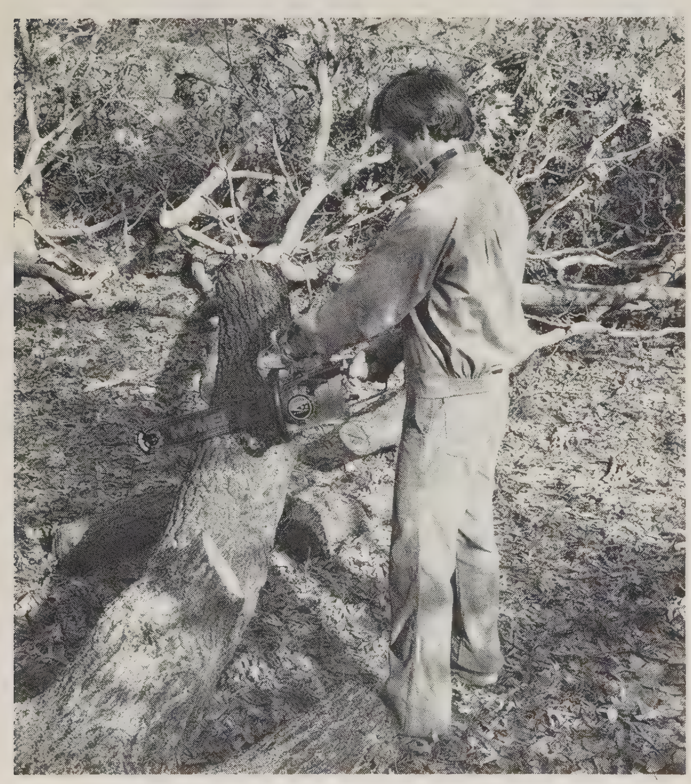


FIG. 11-18 A chain saw must be used in many different positions. *(Homelite Division of Textron, Inc.)*

REVIEW QUESTIONS

1. Explain the basic differences between the two-cycle and the four-cycle engine.
2. Explain how the valves in the four-cycle engine are operated.
3. Why must the camshaft revolve only half as fast as the crankshaft?
4. What are the four strokes in the four-cycle engine? Explain what happens during each stroke.
5. Why must the four-cycle engine have an extra piston ring?
6. What is meant by valve timing? Describe the timing of the valves in a typical engine.
7. Why does the intake valve stay open after the piston passes BDC?
8. Explain the purpose of the automatic compression release and how it works.
9. Explain the differences between the L-head and the I-head engine.
10. What are the three basic operating positions of the crankshaft in small engines?
11. Explain the various ways you can tell a two-cycle engine from a four-cycle engine.

SELF PROJECTS

1. Locate a cylinder block with the head removed. Take a pencil and a sheet of paper and sketch the outline of the top of the block. Then draw a big circle to represent the cylinder. Next, examine the holes in the blocks for threads. Threaded holes are for the cylinder-head bolts. Note how four or five bolt holes are spaced around the cylinder so the gasket can be evenly compressed to seal the combustion chamber when the bolts are tightened. Then locate and mark on your drawing the positions of any dowels that are used to align the head during installation.
2. Go through this same procedure with several different engines and add the pages to your notebook. Be sure to note on each drawing the make, model number, and year the engine was made. Follow this procedure, and soon you will be able to tell instantly what each hole is in any engine block or head. And you will know many important facts about the engines.

12 Chapter

Small-Four-Cycle-Engine Construction

After studying this chapter, you should be able to:

1. **Describe the different valve arrangements used in four-cycle engines**
2. **Explain why the camshaft turns at one-half crankshaft speed**
3. **Define "cylinder block"**

○ 12-1 CYLINDER BLOCK In the four-cycle engine, the head and cylinder are always separate, as shown in Fig. 12-1. If there is more than one cylinder in the engine and if the cylinders are all in one piece, or casting, that part is called the *cylinder block*. For example, the engine shown partly disassembled in Fig. 12-2 has two cylinders in one casting. This part is called the cylinder block. The two cylinders are side by side and parallel, or in a single row. When the cylinders line up this way, the engine is called an *in-line* engine.

The cylinder block shown in Fig. 12-3 is for a four-cylinder in-line outboard engine. The four cylinders are lined up in a single row. In this engine, the valves are installed overhead, or in the cylinder head, as shown in Fig. 12-4. The lack of fins on the cylinder block and head tells us that the engine is water-cooled.

In some V-type engines, each cylinder is separate, as shown in Fig. 12-5. In other engines, the two cylinders on each bank are cast together. However, many V-type engines use only one cylinder head for each bank of cylinders. The engine shown in Fig. 12-5 has overhead valves.

Figure 12-6 shows an opposed-piston two-cylinder four-cycle engine. This also is called a flat, or pancake, engine. Notice that the engine shown in Fig. 12-6 is an L-head engine. It has the valves located in the cylinder block.

○ 12-2 CRANKSHAFT In single-cylinder engines, particularly high-speed engines, the crankshaft may be a built-up part. Figure 10-9 shows a crankshaft of this type in a disassembled view. Figure 12-7 shows the crankshaft assembled. The two round plates form the flywheel and counterweights for the crankshaft. Multiple-cylinder engines also may use a built-up crankshaft.

Many small engines use a built-up crankshaft of the type just described. However, most small engines

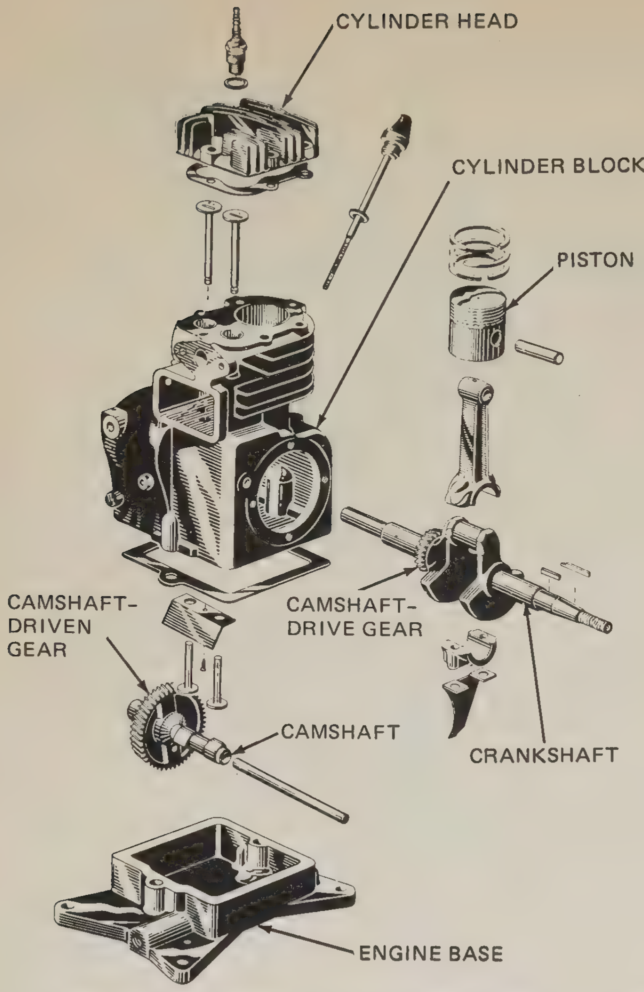


FIG. 12-1 Disassembled view of a one-cylinder four-cycle engine. The head and cylinder block are separate parts. *(Clinton Engines Corporation)*

used in lawn mowers and similar equipment have a one-piece crankshaft such as shown in Fig. 12-8.

Many high-speed engines of the type used in motorcycles have a built-up crankshaft. These engines are usually equipped with ball and roller-type bearings for low friction and high engine performance (see ○ 9-7).

Other multiple-cylinder engines use a single-piece crankshaft, such as shown in Fig. 12-9. Here we show the single-piece crankshaft for a small four-cylinder in-line engine. The main bearings and main-bearing caps also are shown. This crankshaft is very similar to the crankshaft used in the typical small automobile engine. Figure 12-5 is a cutaway view of a four-cylinder air-cooled engine using a one-piece crankshaft such as shown in Fig. 12-9.

○ 12-3 VALVE ARRANGEMENTS Small four-cycle engines use various valve arrangements, including the L-head and the I-head, or overhead-valve, types. The L-head engine has the valves in the cylinder block as shown in Fig. 12-6. This type of engine also is called a side-valve engine, because the valves are along the side of the cylinder. The valve train for an L-head engine is shown in Fig. 12-10.

The overhead-valve, or I-head, engine has additional parts to operate the valves, as described in ○ 11-9. These parts include the push rods, rocker arms, and the supports for the rocker arms. The support often is a shaft on which the arms can rock, such as shown in Fig. 12-5. Instead of a shaft, many engines use ball joints on which the rocker arms mount and pivot, as shown in Fig. 12-11.

The valves do not actually have to be up "overhead" in the I-head engine. In some engines, the cylinder may be horizontal or at an angle from the vertical. Many small engines have their cylinders inclined in this way. Figure 12-5 shows the arrangement for a Wisconsin engine. Note that two separate rocker-arm shafts are required, one on each head. In each cylinder, the two push rods are parallel to each other. In many engines the exhaust valve is smaller than the intake valve. The intake valve usually is larger, because the only pressure pushing the air-fuel mixture into the cylinder when the intake valve is open is atmospheric pressure. But when the exhaust valve is open, there is considerably greater pressure on the exhaust gases. Therefore, a smaller exhaust valve is satisfactory.

Engines with overhead valves using push rods are often called push-rod engines. There is another type of overhead-valve engine which does not use push rods. The camshaft is mounted overhead also. Figure 12-4 shows an engine of this type.

Figure 12-5 is a cutaway view of a four-cylinder V-type push-rod engine. The general construction can be seen from the illustration. The valve lifter is a tappet which rides on the camshaft cam. The push rods are enclosed in hollow tubes. Oil is sent to the cylinder head from the oil pump. The oil lubricates the upper end of the push rod, the rocker-arm shafts, and the valve stems. The oil then flows down to the oil sump at the bottom of the engine.

○ 12-4 OVERHEAD CAMSHAFT ENGINES In many high-performance motorcycle and outboard engines, the camshaft is mounted in bearings in the cylinder head (Fig. 12-4). This eliminates the need for push rods. Also, in some engines, the cams work directly on the valve lifters or cam followers which are positioned under the valve stems (Fig. 12-4). This eliminates the need for rocker arms. With these parts eliminated, the engine is more flexible. The valves respond more quickly. Higher engine speeds are possible because there are fewer parts to move. The inertia of the valve train is reduced, and there is less bending in the valve train.

Many modern automotive and motorcycle engines

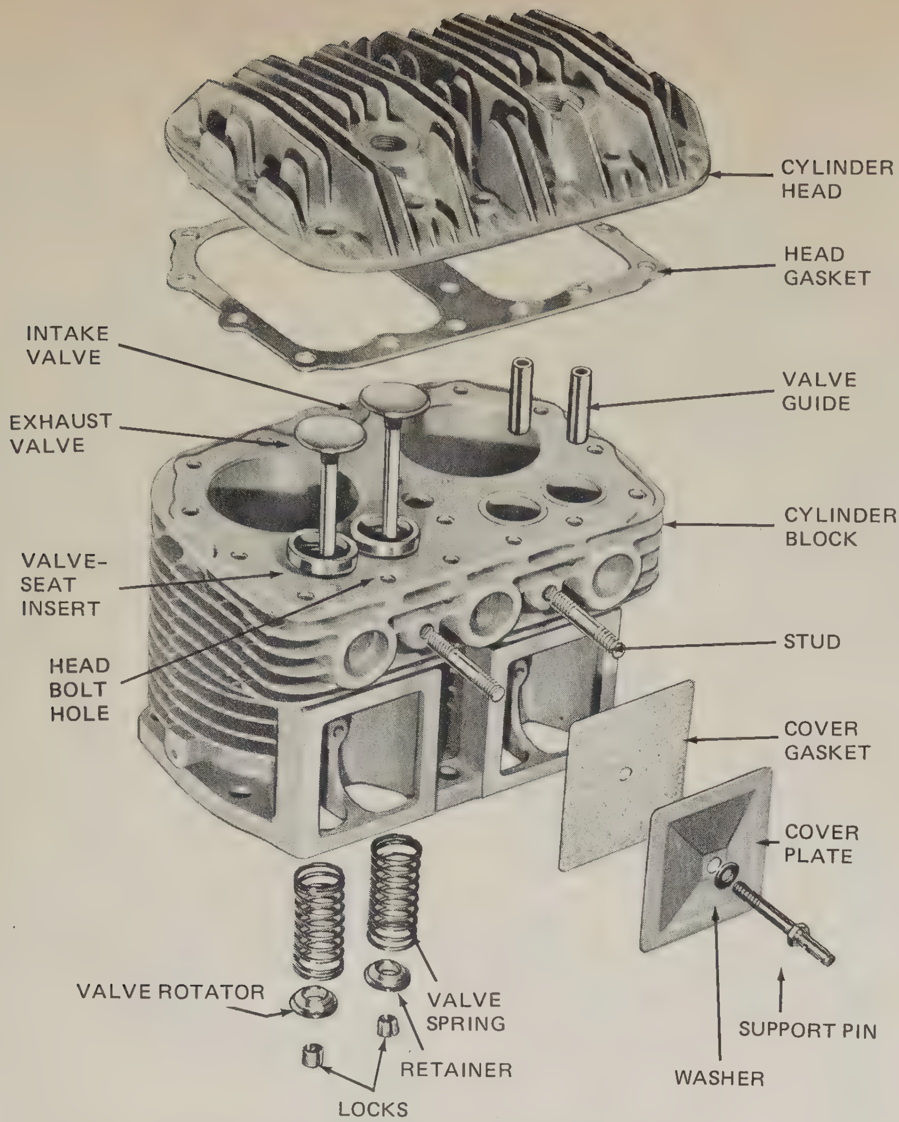


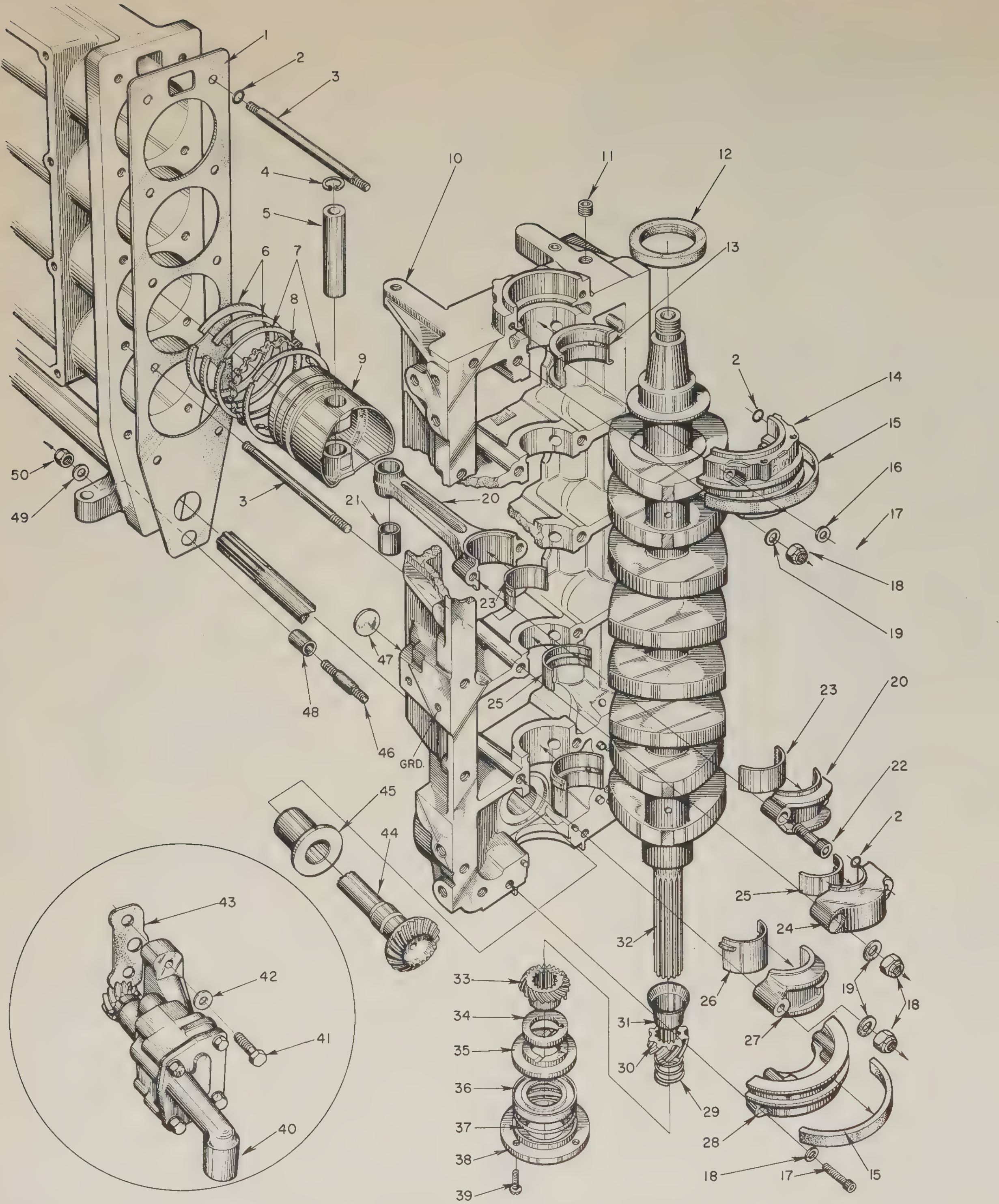
FIG. 12-2 Disassembled view of a two-cylinder in-line four-cycle engine. *(Wisconsin Motor Corporation)*

are of the overhead camshaft type. An engine with a single overhead camshaft in the head is called a single-overhead-camshaft (or SOHC) engine. Figure 12-4 shows an engine with a single overhead camshaft. If the engine has two camshafts in the head, it is called a double-overhead-camshaft (DOHC) engine. Usually the "shaft" is dropped, and so the terms become "single-overhead-cam engine" and "double-overhead-cam engine."

To improve the "breathing" of the engine, some engines have more than two valves for the cylinder. By "breathing" we mean this: When you breathe, your lungs draw in air and then push it out. The engine does something similar. When the piston moves down on the intake stroke, the air-fuel mixture is drawn into the cylinder. Then, when the piston moves up on the exhaust stroke, the burned gases are pushed out of the cylinder.

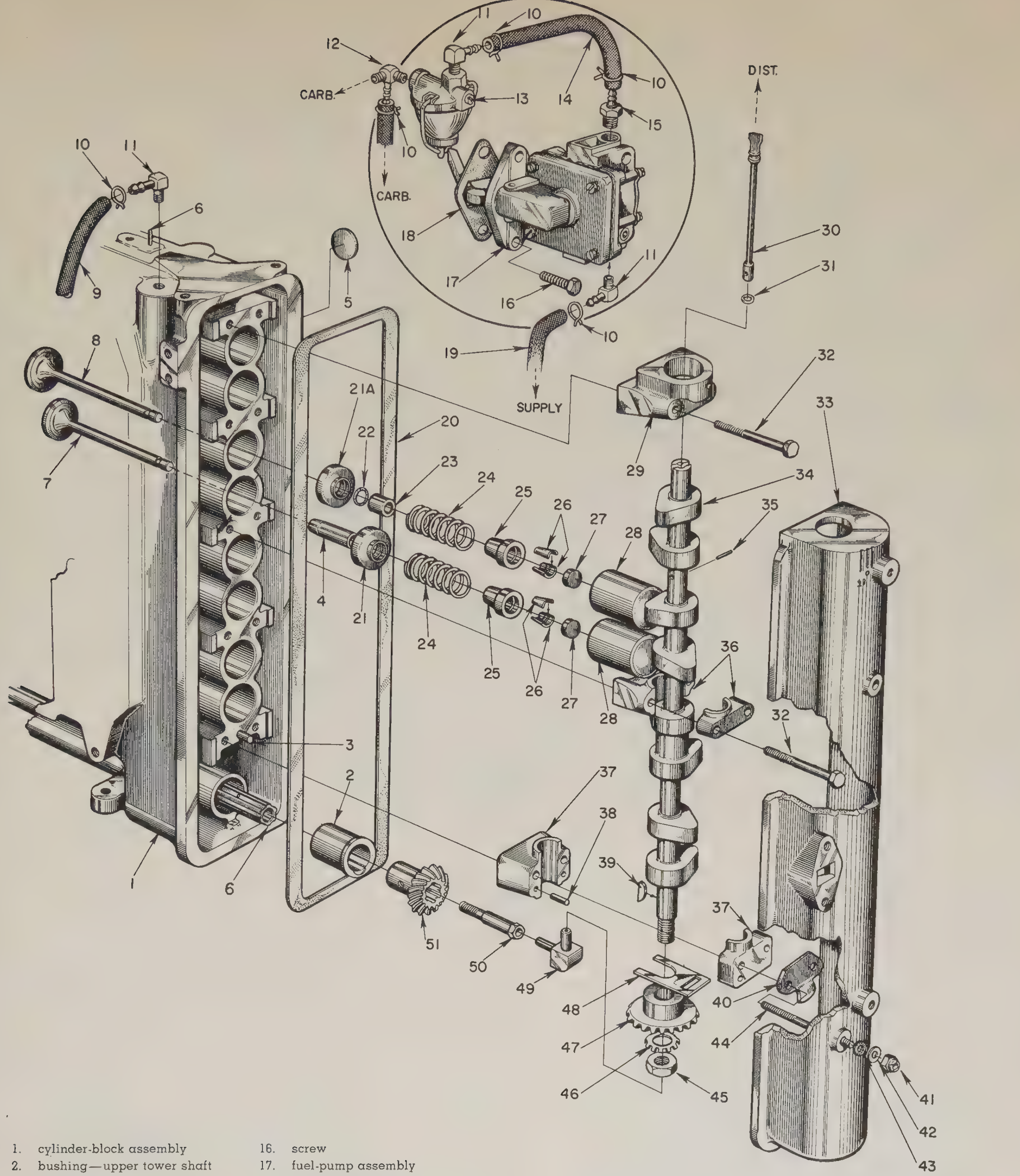
○ 12-5 GEAR AND CHAIN DRIVES FOR CAMSHAFTS In many small engines, gears are used to drive the camshaft, as shown in Figs. 12-1, 12-4, 12-5, and elsewhere in the book. Overhead camshaft engines can use sprockets and chain or belt to drive the camshaft. The end result is the same, however. The camshaft is driven at half the speed of the crankshaft. This is because the crankshaft gear or sprocket has only half the number of teeth as the camshaft gear or sprocket.

There is one difference worth noting, however. With gears, the camshaft turns in the opposite direction of the crankshaft. This is because two gears in



1. gasket—cylinder block
2. O ring—crankcase studs, main caps
3. stud—cylinder
4. ring—piston pin retaining
5. pin—piston
6. ring—piston—compression
7. ring—piston—oil
8. expander—oil ring
9. piston
10. crankcase assembly
11. plug—pipe oil tubes
12. seal—oil
13. bearing—rear main (flywheel end)
14. cap—rear main bearing
15. seal—bearing and seal caps
16. washer—bearing and seal caps
17. screw—socket hd.
18. nut—hexhead, elastic stop
19. washer—bearing cap
20. connecting rod assembly
21. bushing
22. screw
23. bearing—connecting rod (2 piece)
24. cap—center main bearing
25. bearing—center main (2 piece)
26. bearing—front main
27. cap—front main bearing
28. cap—front seal
29. spring—crankshaft gear
30. gear—drive, oil pump
31. spacer—drive gear (oil pump)
32. crankshaft
33. gear assembly—crankshaft
34. spacer—crankshaft gear
35. bearing—gear thrust
36. seal—oil (thrust bearing)
37. O ring—bearing retainer
38. retainer—thrust bearing
39. screw
40. oil-pump assembly
41. screw
42. washer—flat
43. gasket—oil pump
44. tower shaft assembly
45. bushing—lower tower shaft
46. stud—crankcase to block
47. plug—Welch
48. sleeve—dowel
49. washer
50. nut

FIG. 12-3 Crankshaft, cylinder block, and related parts for a four-cylinder four-cycle outboard engine. *(Homelite Division of Textron, Inc.)*



1. cylinder-block assembly
2. bushing—upper tower shaft
3. pin—dowel, camshaft bearing
4. guide—valve
5. Welch plug
6. tower shaft
7. valve exhaust
8. valve—intake
9. line—water tell-tale
10. clamp
11. elbow—water line
12. fitting—fuel strainer
13. fuel strainer assembly
14. line—fuel, pump to strainer
15. nipple—pump outlet
16. screw
17. fuel-pump assembly
18. gasket—fuel pump
19. line—fuel, pump to coupling nipple
20. gasket—camshaft cover
21. roto-cap—valve (exhaust only)

21A. spacer-valve (intake only)

22. O ring—intake valve
23. cap—O ring retainer (intake only)
24. spring-valve
25. retainer—valve spring
26. lock—valve spring retainer (halves)
27. spacer—cam follower
28. cam follower
29. bearing—camshaft (distributor end)
30. key—distributor drive
31. O ring—distributor key
32. screw
33. cover—camshaft
34. camshaft
35. pin—dowel
36. bearing assembly—center camshaft (two pieces)
37. bearing assembly—camshaft (tower shaft end)
38. pin
39. key—Woodruff
40. locator—thrust washer
41. nut—hex, elastic stop
42. washer—flat
43. gasket—cover stud
44. stud—camshaft cover
45. nut—hex, gear to camshaft
46. lockwasher
47. gear—camshaft
48. spacer—camshaft thrust
49. elbow—oil metering
50. adjuster—tower shaft
51. gear—upper tower shaft

FIG. 12-4 Partly disassembled view of engine showing fuel pump, camshaft, valves, and related parts. *(Homelite Division of Textron, Inc.)*

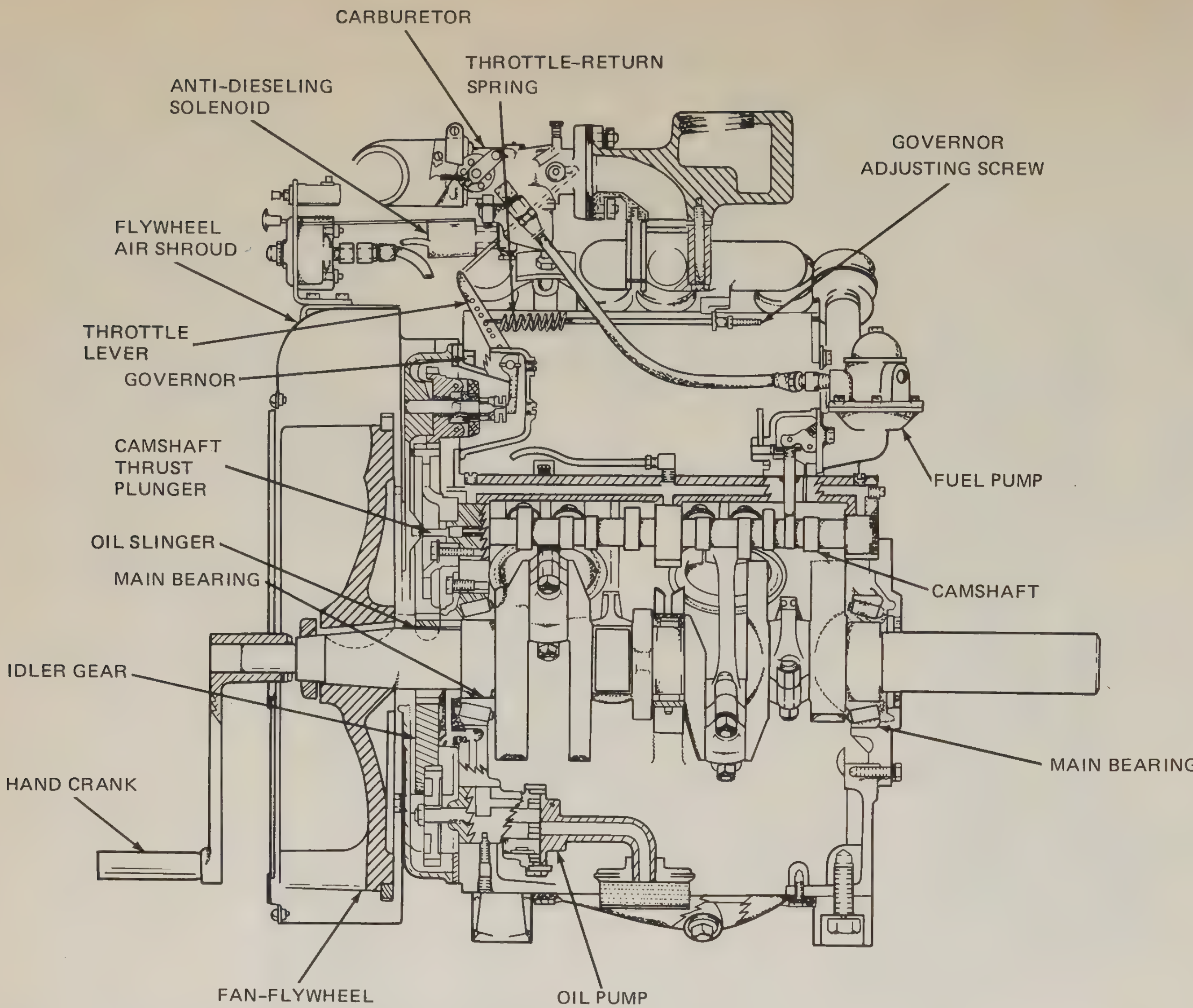


FIG. 12-5 An air-cooled V-4 type of four-cycle engine (left) in side sectional view, and (right, next page) in end sectional view. *(Teledyne Wisconsin Motor)*

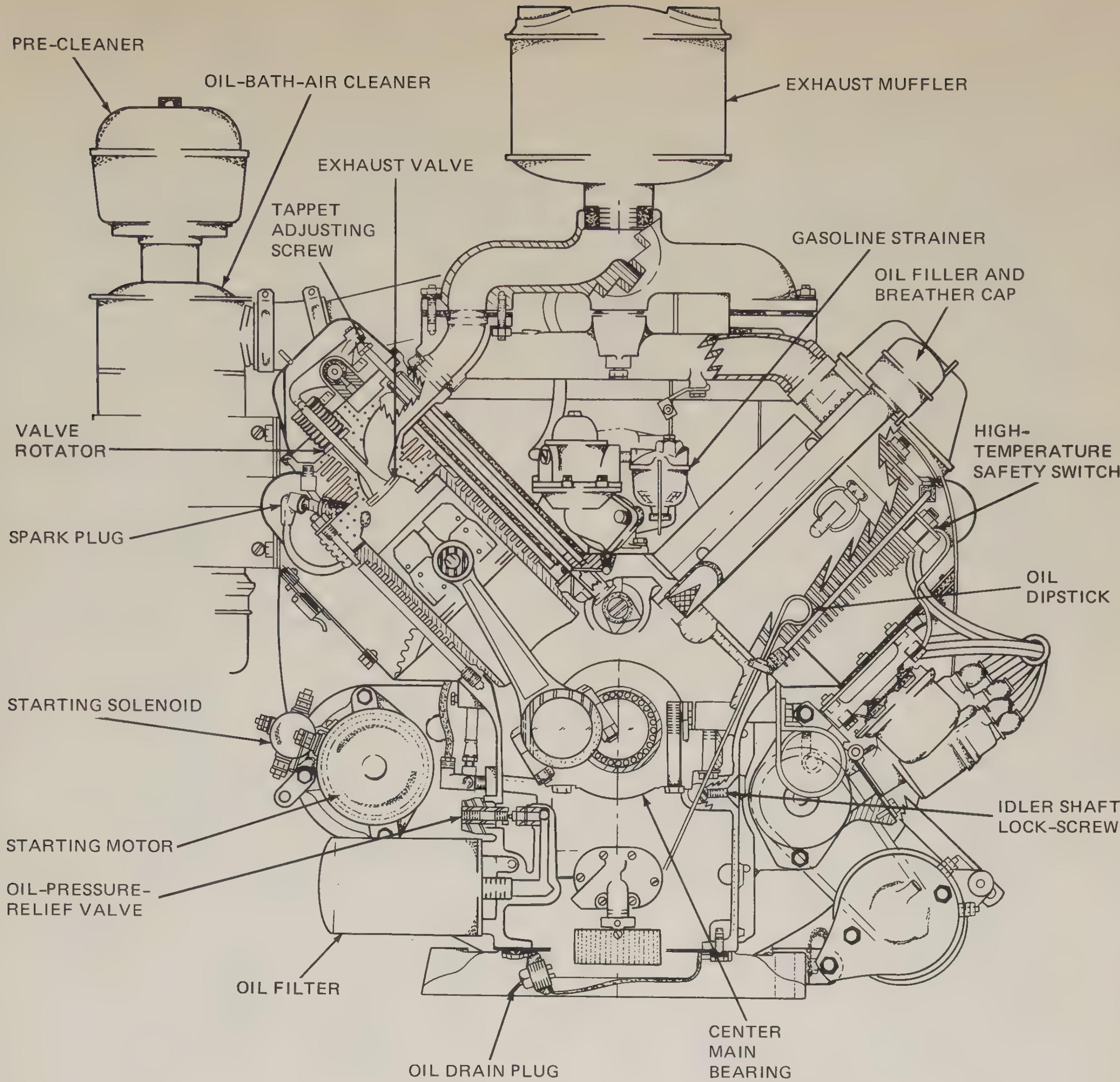
mesh turn in opposite directions, as shown in Fig. 12-12. However, two sprockets driven by a chain or belts both turn in the same direction, as shown in Fig. 12-13. This difference in rotation requires two different camshaft arrangements. The cam lobes must be located differently for the two types of drive.

Timing chains and belts usually have some form of tensioner. The tensioner is either a slide of some sort or a spring-loaded idler sprocket. The purpose of the tensioner is to take up all looseness in the chain. This prevents erratic valve action and minimizes noise.

○ 12-6 PISTONS Many piston heads have a complex shape. Look at Figs. 2-4 and 12-14. Notches or recesses have been cut out of the piston head shown in Fig. 12-14 to provide room for the valve heads. The notches prevent the piston from striking the valves as the piston approaches TDC. Therefore, the piston can be designed to move closer to the cylinder head on the compression stroke.

REVIEW QUESTIONS

1. What are the three types of valve trains?
2. How many cams are there on the camshaft for a two-cylinder engine?
3. What are three types of camshaft drives?
4. How many times does the crankshaft turn while the camshaft turns once?
5. Which is larger, the intake valve or the exhaust valve? Why?
6. Which valve runs hotter, the intake valve or the exhaust valve?



7. How is the ball-pivot rocker arm adjusted?
8. How is the spring attached to the end of the valve stem?
9. Explain the advantages of the overhead-camshaft engine.
10. What do SOHC and DOHC mean?

SELF PROJECT

The valve train is only as good as the camshaft that operates it. So examine camshafts. Count the number of lobes. If there is one more than the engine has valves, check the contours until you locate the eccentric that operates the fuel pump. Take a sheet of paper and, starting at the top, write down the make and model of engine from which the camshaft came. Then start at the front of the camshaft and identify each cam. Many camshafts will start with the cam for cylinder number 1 exhaust valve. So write down "1E" to start the column under the line where you wrote in the engine make and model.

You may be in for a surprise. For example, if you are checking the camshaft from a V-type engine, you may find that the second cam is for the exhaust valve for cylinder number 2. On some V-type engines, the cams interlace like the fingers on your

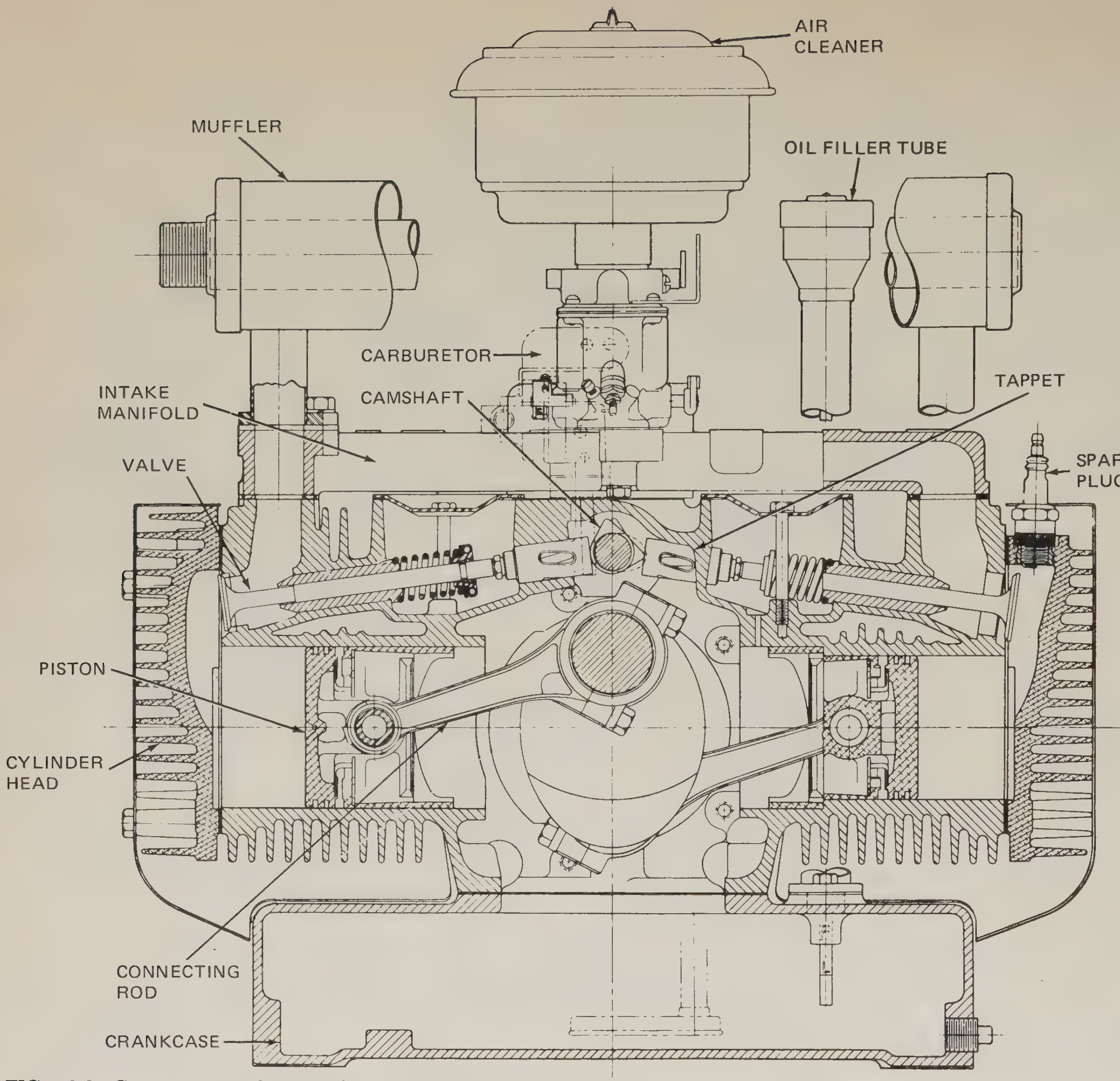


FIG. 12-6 Cross-sectional view of an opposed piston two-cylinder four-cycle engine. *(Onan Corporation)*

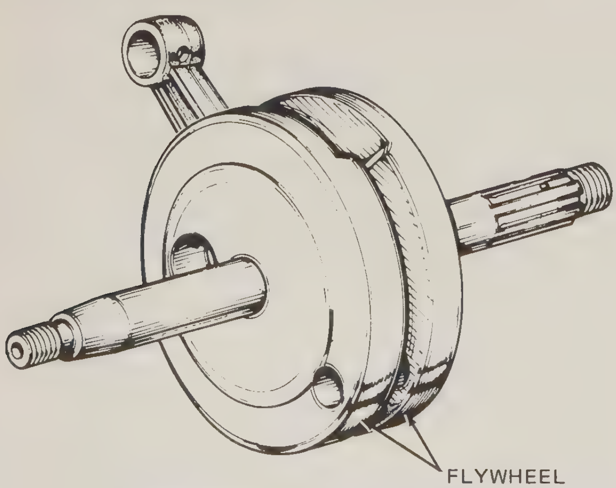


FIG. 12-7 An assembled built-up crankshaft for a single-cylinder four-cycle engine. *(Honda Motor Company, Ltd.)*

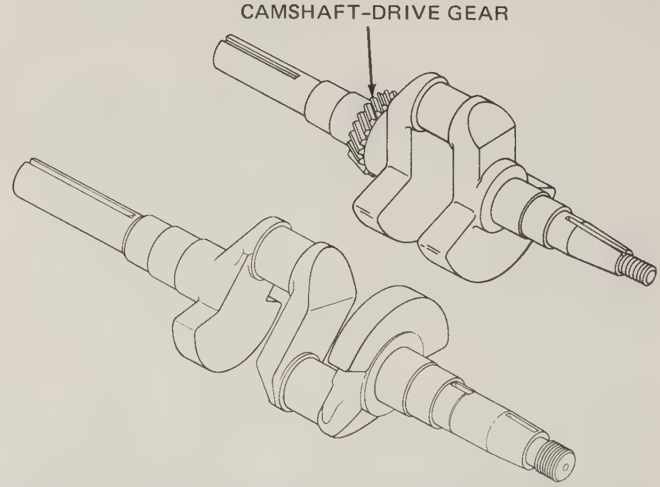


FIG. 12-8 One-piece crankshaft (top) for a one-cylinder engine and (bottom) for a two-cylinder engine. *(Kohler Company)*

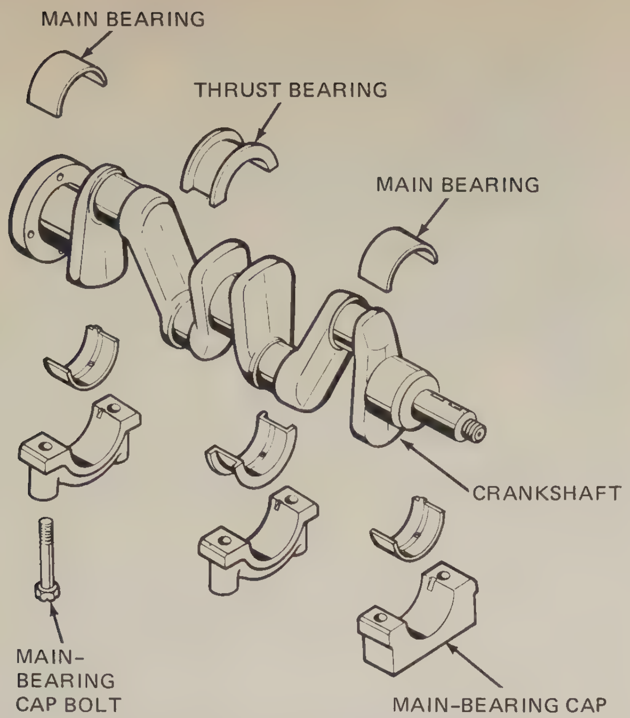


FIG. 12-9 A one-piece crankshaft for an in-line four-cylinder four-cycle engine. *(The J. I. Case Company)*

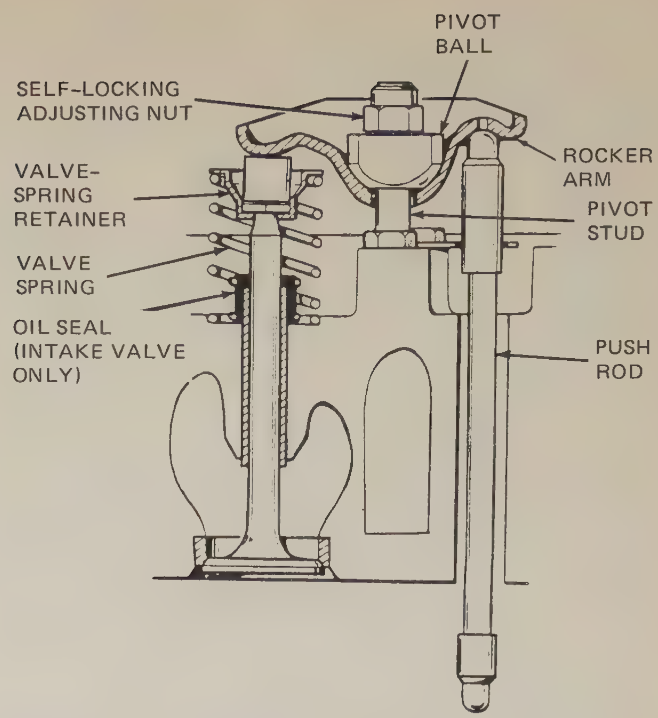


FIG. 12-11 Overhead-valve train for a small engine. *(Onan Corporation)*

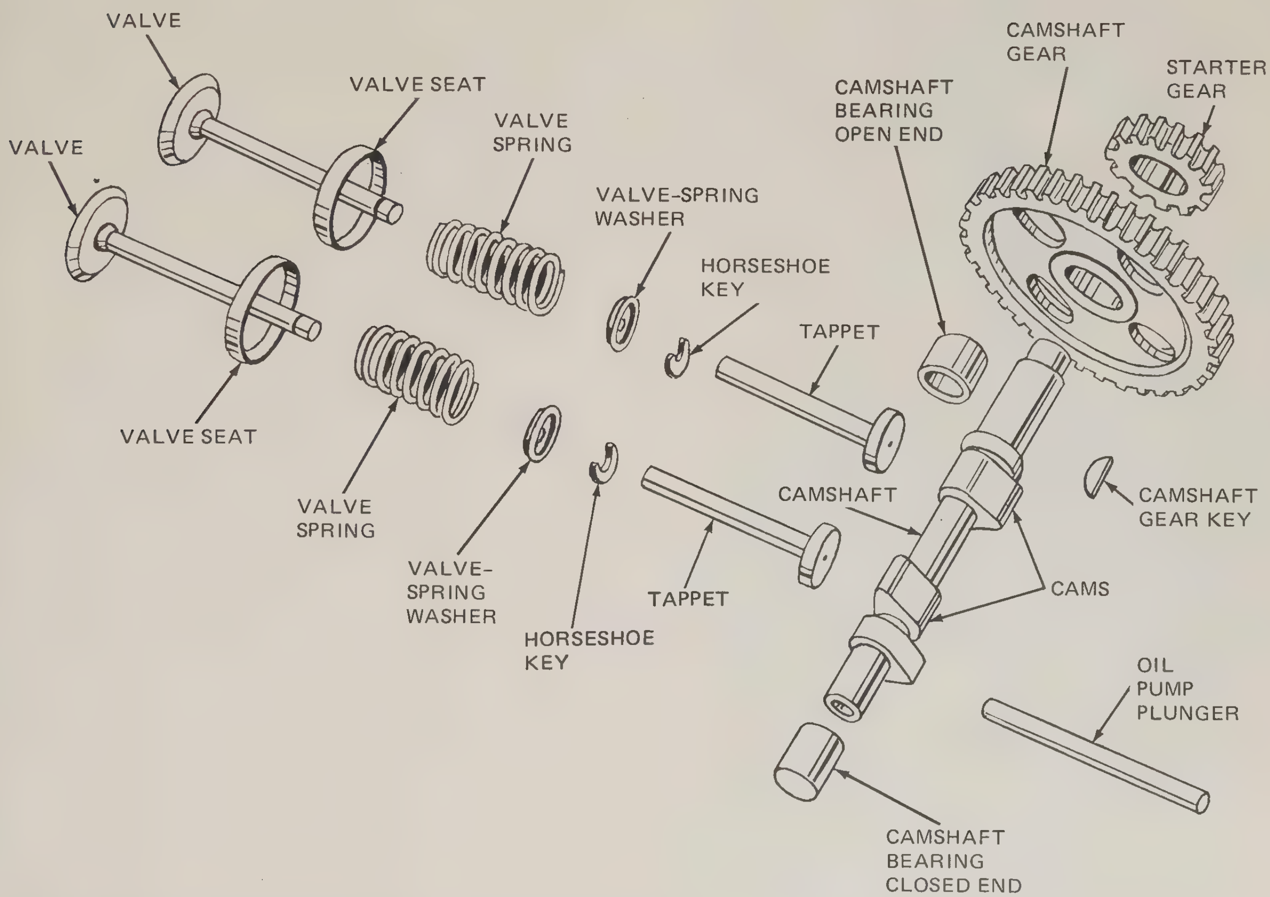


FIG. 12-10 Complete valve train for a one-cylinder L-head engine. *(Cushman Motors Division of Outboard Marine Corporation)*

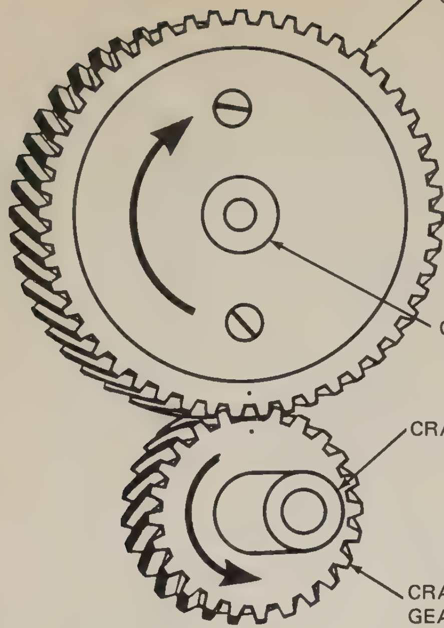


FIG. 12-12 Two meshed gears turn in opposite directions.

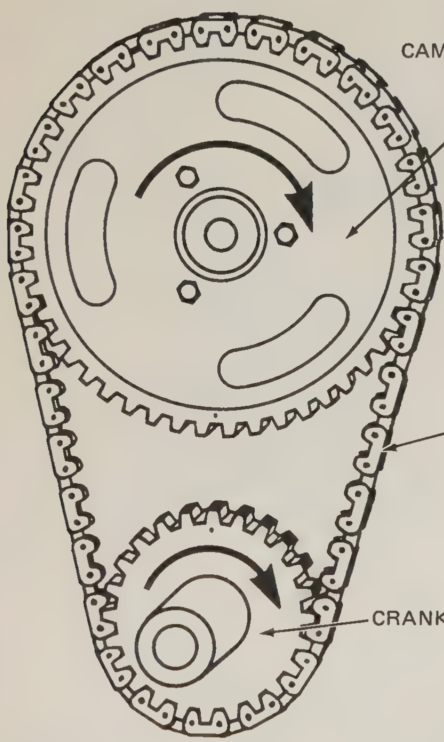


FIG. 12-13 In a sprocket-and-chain drive, the two sprockets turn in the same direction.

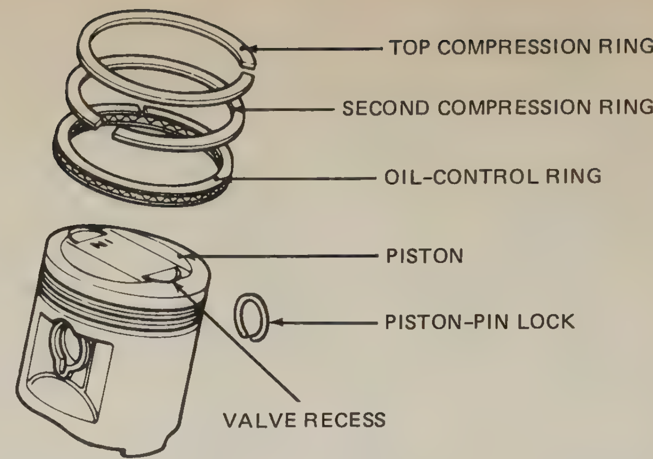


FIG. 12-14 Set of rings for one piston in a four-cycle engine. *(Honda Motor Company, Ltd.)*

two hands when you interlock your fingers. Continue your examination until you have identified all the cams and have completed the column. Prepare additional cam sheets until you can look at an engine and camshaft and identify all the cams. File the cam sheets in your notebook.

13 Chapter

Wankel Engines

After studying this chapter, you should be able to:

1. **Explain what a Wankel engine is**
2. **List the differences in construction between a Wankel engine and a piston engine**
3. **Describe the actions of the rotor as it revolves**
4. **Define "two-rotor Wankel engine"**

○ 13-1 WANKEL APPLICATIONS Most Wankel engines have been used in automobiles. However, a snowmobile has been built with a Wankel engine in it. The installation is shown in Fig. 13-1. Figure 13-2 shows in cutaway view a two-rotor Wankel engine installed as a stern-drive engine in a boat. Suzuki, Yamaha, and Hercules, each a manufacturer of motorcycles, have sold or shown models with Wankel engines in them.

Toyo Kogyo calls the Wankel engine the Mazda rotary. The Wankel engine also is known as a rotary combustion (RC) engine because of the way the combustion chambers rotate. Suzuki called their motorcycle a rotary engine (RE) model.

There is a basic difference between the piston engine and the Wankel type of rotary engine. (There are other types of rotary engines, such as the gas-turbine engine.) In the piston engine, pistons move up and down, or reciprocate, in the cylinder. In the Wankel engine, a rotor spins in a fat figure-eight-shaped cylinder. The rotor does not reciprocate. It rotates.

○ 13-2 WANKEL-ENGINE CONSTRUCTION Figure 13-2 is a cutaway view of a two-rotor Wankel engine, with an attached stern-drive unit. Since both rotors work the same way, we will concentrate on the actions of a single rotor.

The rotor is enclosed on its two sides by flat housings. The rotor housing in which the rotor turns is shaped somewhat like a very fat figure eight, as shown in Fig. 13-3. This shape is called an epitrochoid curve. The rotor has three lobes, or apexes, as shown in Fig. 13-4, and turns in the rotor housing. The rotor is sealed on its two sides to the two flat side housings. Figure 13-5 shows how the rotor fits into the rotor housing. The seals on the tips of each lobe are in contact with the inner face of the rotor housing. The rotor rotates in an eccentric pattern in the housing, as shown in Fig. 13-6. As the rotor turns, each of the three rotor lobes follows the curve of the rotor hous-

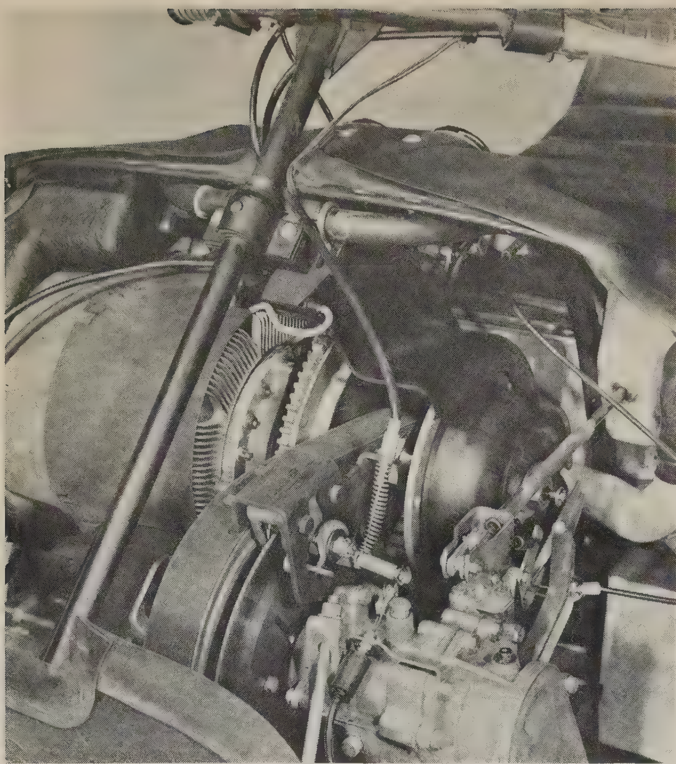


FIG. 13-1 A Wankel rotary-combustion engine mounted in a snowmobile. *(Outboard Marine Corporation)*

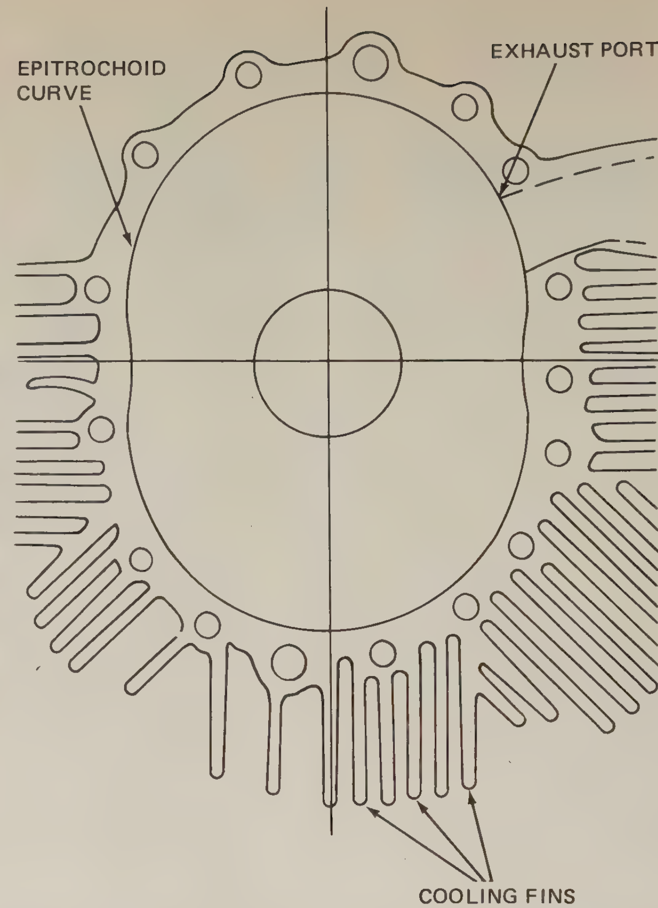


FIG. 13-3 Rotor housing. *(Yanmar Diesel Engine Company, Ltd.)*

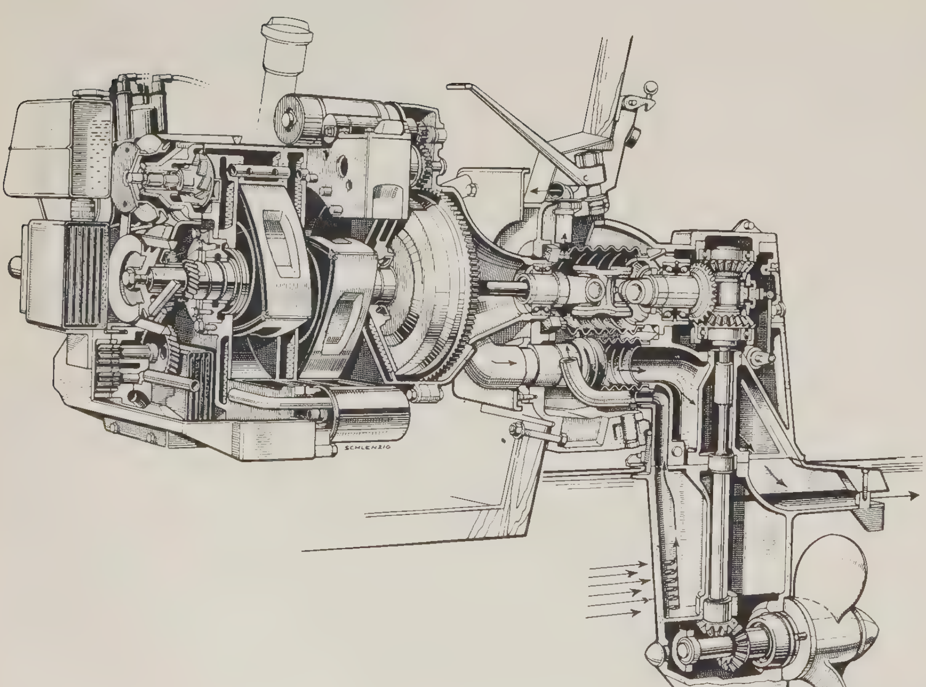


FIG. 13-2 A two-rotor Wankel engine combined with a stern drive unit to power a boat. *(NSU)*

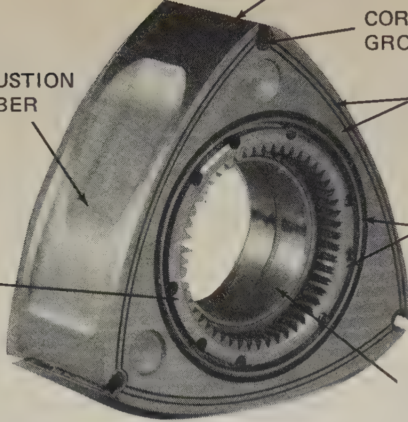


FIG. 13-4 Rotor for Mazda Wankel engine. *(Toyo Kogyo Company, Ltd.)*

ing. In other words, each of the seals on the lobes fits tightly against the inner face of the housing, providing a tight seal. This produces three separate chambers sealed from one another. These chambers increase and decrease in volume, as shown in Fig. 13-6. This is like the volume in the cylinder of a reciprocating engine, increasing and decreasing as the piston moves down and up.

The two sides of the rotor are enclosed and sealed by two flat-faced side housings. The front housing encloses one side of the rotor, and the rear housing encloses the other side. Figure 13-7 shows the front housing. The rear housing is similar. Seals in the sides of the rotor provide a good seal between the rotor and the housing.

If the engine has two rotors, an intermediate housing is provided between the rotors, as shown in Fig. 13-2. Figure 13-8 shows how the side housings stack up in one-rotor and two-rotor Wankel engines. Notice the holes around the outer edges of all these housings in Fig. 13-5 and 13-7. These holes are for coolant circulation and are part of the engine cooling system.

FIG. 13-6 The rotor rotates eccentrically, and so the three apexes are always in sliding contact with the inner face of the rotor housing. *(Toyo Kogyo Company, Ltd.)*

○ 13-3 WANKEL-ENGINE OPERATION Figure 13-9 shows the complete series of actions that occur during one revolution of the rotor. There are four stages

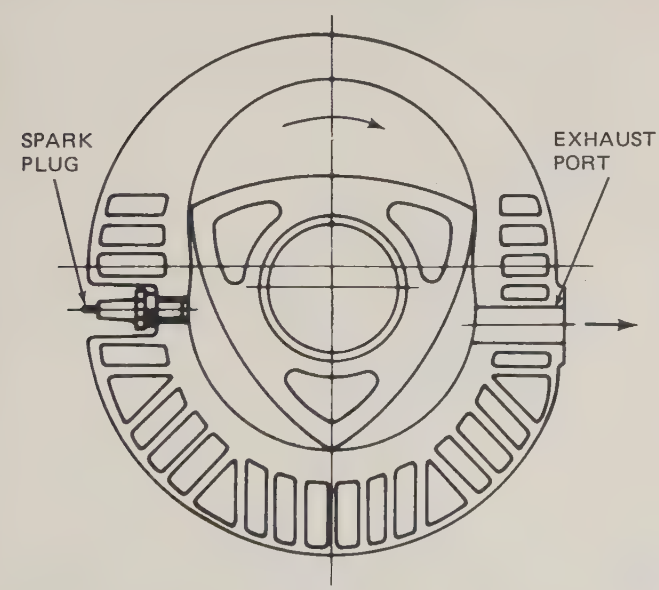


FIG. 13-5 How the rotor fits into the rotor housing.

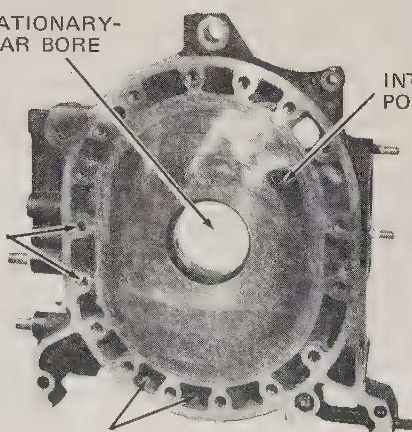


FIG. 13-7 Front side housing. Note the large holes around the outer edge for coolant flow. Note the intake port to the right of the stationary gear bore. The small round holes are bolt holes. *(Toyo Kogyo Company, Ltd.)*

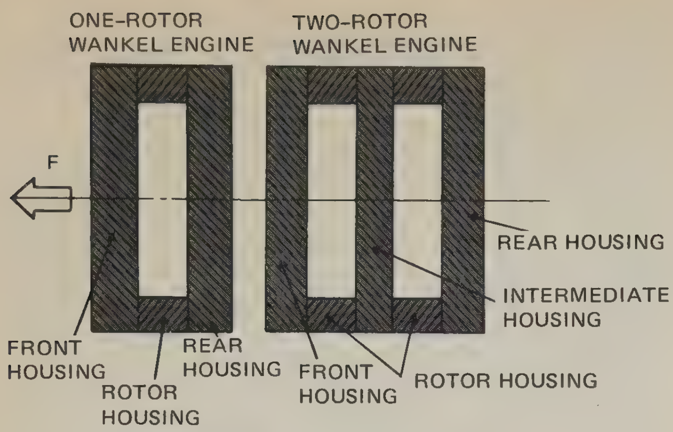


FIG. 13-8 How the side and rotor housing stack up in a one-rotor and a two-rotor Wankel engine. *(Toyo Kogyo Company, Ltd.)*

in the action cycle. Let us start at *(a)* in the upper center of Fig. 13-9. Here the rotor has moved around so that one of the rotor lobes has cleared the intake port, as shown at number 1. As the rotor continues to rotate (clockwise) in Fig. 13-9, the space between the rotor and housing increases, as shown at 2 in *(b)*. This produces a partial vacuum, which causes the air-fuel mixture to enter, as shown by the small arrow under 2. This is the same action as in the piston engine when the piston moves down on the intake stroke. As the rotor moves further around, the space between it and the housing continues to increase. See 3 in *(c)* and 4 in *(d)*. When the rotor reaches the point shown in *(d)*, the trailing lobe passes the intake port. Now the mixture is sealed between the two lobes of the rotor, as shown at 5 in *(e)*.

Now let us follow the mixture as the rotor continues to turn. Look at *(f)*. Here the mixture, shown at 6 in *(f)*, is starting to be compressed. The compression continues through 7 in *(a)*. At 8 in *(b)*, the mixture is nearing maximum compression. This is the same as the piston approaching TDC on the compression stroke.

Next combustion takes place. At 9 in *(c)*, the spark plugs fire and the compressed mixture is ignited. Now the hot gases push against the rotor and turn it farther around, as shown in 10 in *(d)*. The hot gases continue to expand, as shown at 11 in *(e)* and 12 in *(f)*. This is the same as the power stroke in the piston engine.

Note that the engine uses two spark plugs. This gives more complete burning of the air-fuel mixture, thereby reducing exhaust emissions. The combustion chamber formed by the housings and rotor is long and narrow. The two plugs give more complete burning of the air-fuel mixture. However, other Wankel engines are operating satisfactorily with a single spark plug.

At 13 in *(a)*, the leading lobe of the rotor is clearing

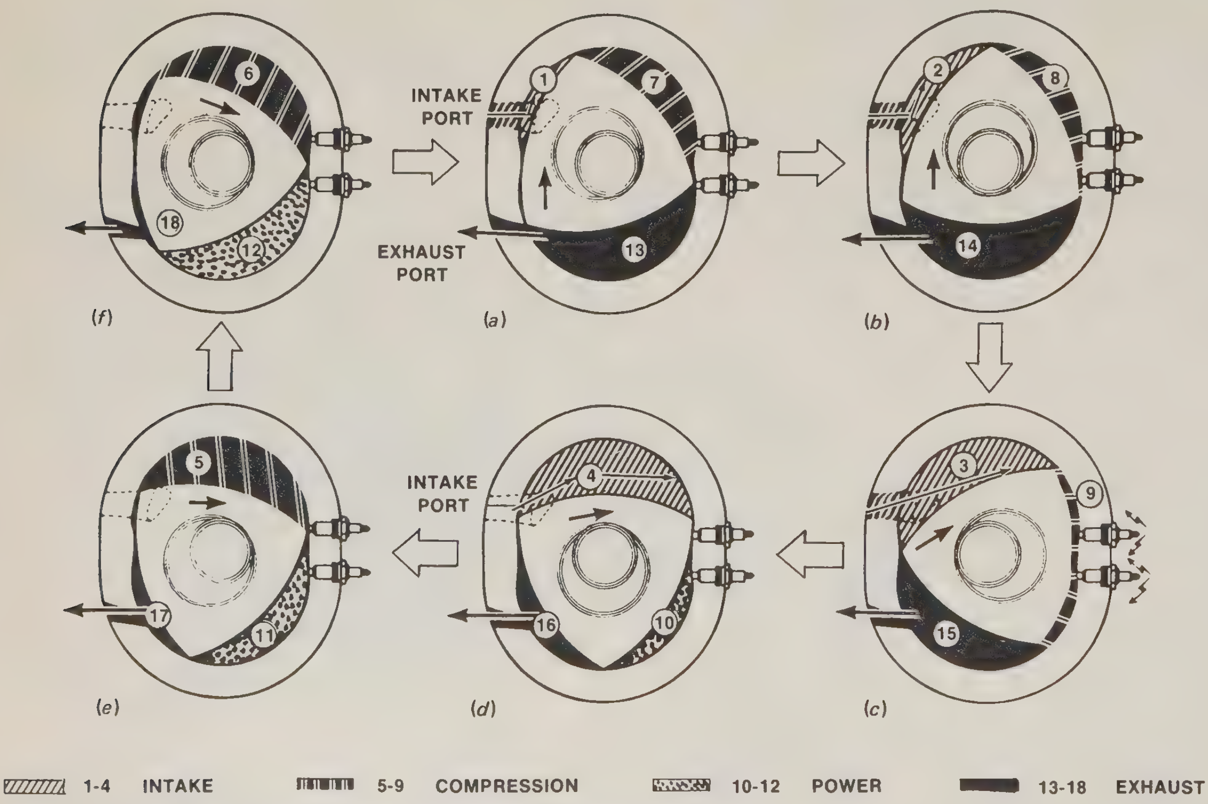


FIG. 13-9 Principle of Wankel-engine operation. Follow the actions from *(a)* to *(f)* and from numbers 1 to 18. This takes you through the complete cycle of actions between two apexes of the rotor.

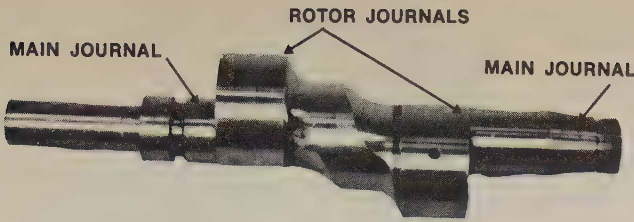


FIG. 13-10 Eccentric shaft. *(Toyo Kogyo Company, Ltd.)*

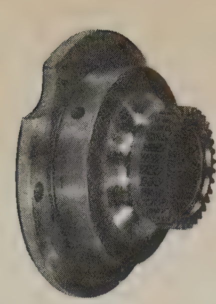


FIG. 13-12 Stationary gear which is mounted in the side housing. *(Toyo Kogyo Company, Ltd.)*

the exhaust port in the housing. Now the burned gases begin to exhaust from the space between the rotor lobes. This exhaust continues through 14 in *(b)*, 15 in *(c)*, 16 in *(d)*, 17 in *(e)*, and 18 in *(f)*. By that time, the leading rotor lobe is clearing the intake port, as shown at 1 in *(a)*. Now the whole chain of events takes place again.

We have looked at the actions taking place between one pair of rotor lobes. But there are three lobes and three chambers between the lobes. Therefore, there are three sets of actions going on at the same time in the engine. There are three power thrusts for every rotor revolution. With a two-rotor engine, there are six power thrusts for every revolution of the two rotors.

○ 13-4 GETTING THE POWER TO THE CRANKSHAFT Now let us see how the rotor transmits power to the crankshaft, or, more accurately, to the eccentric shaft. Figure 13-10 shows the eccentric shaft of a two-rotor engine. The shaft is supported by two main bearings. It has two rotor journals which are offset as shown. Figure 13-11 shows how a rotor fits on one of the eccentric rotor journals and how the push on the rotor makes the eccentric shaft rotate. The arrows show the high-pressure gas pushing against the rotor. Most of the push is below the center of the eccentric shaft. This makes the shaft turn at the same time the rotor revolves. The offset rotor journals on the eccentric shaft do the same job as the crankpins on the crankshaft of a piston engine.

A stationary gear meshes with the internal gear of the rotor to control the rotation of the rotor. You can see the internal gear in the rotor in Fig. 13-4. The stationary gear is shown in Fig. 13-12. The stationary gear is installed in the side housing. It contains the bearing that supports one end of the eccentric shaft. Figure 13-13 shows how the stationary gear keeps the rotor moving in the proper path. The gear ratio between the rotor gear and the stationary gear is 2:3.

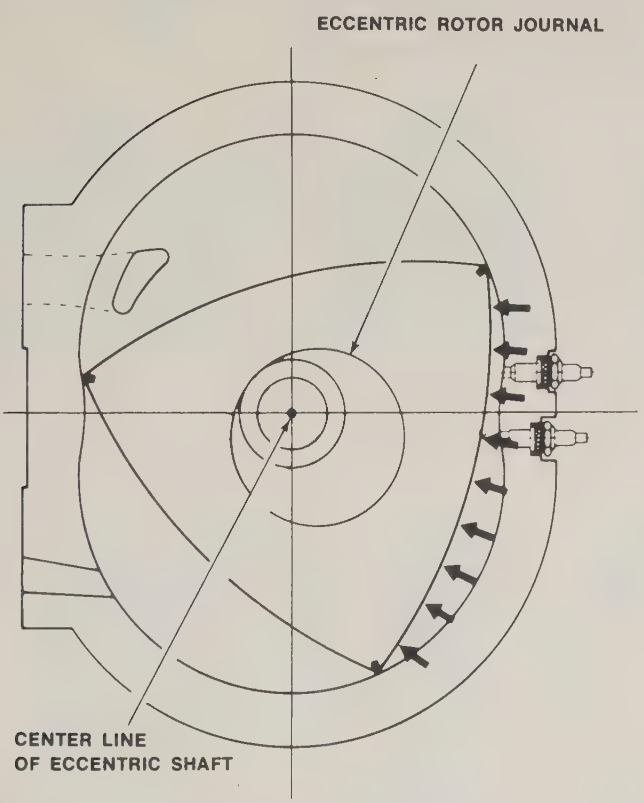


FIG. 13-11 How the combustion pressure, acting off-center on the eccentric of the eccentric shaft, forces the shaft to rotate. *(Toyo Kogyo Company, Ltd.)*

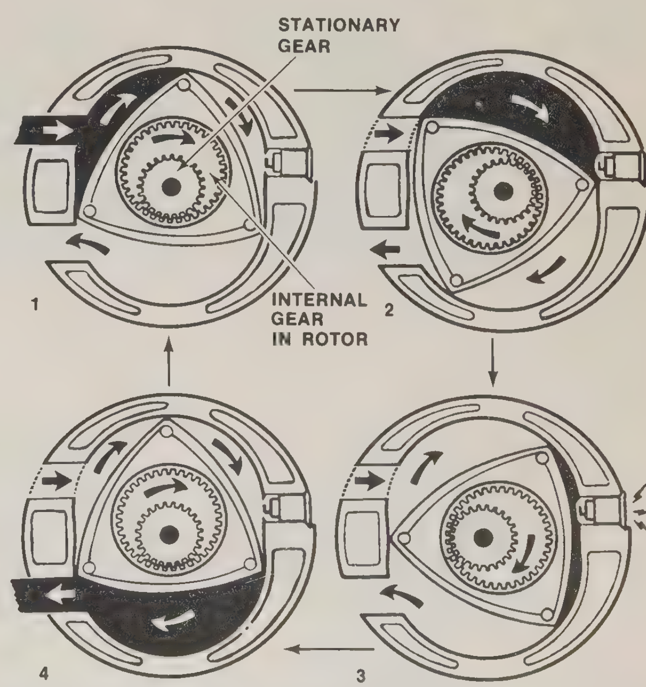


FIG. 13-13 How the rotor rotates eccentrically around the stationary gear. It follows an orbit that keeps all three apex seals in sliding contact with the rotor housing. *(Toyo Kogyo Company, Ltd.)*

○ 13-5 THE 3:1 RATIO You might assume that the rotor and the eccentric shaft rotate together at the same speed. They do not. The eccentric shaft rotates three times while the rotor is rotating only once. Figure 13-14 will help you understand it. Let us follow the rotor during one power thrust.

Start at *(a)* in the upper left corner in Fig. 13-14. The lobe marked "X" is at the lower right. The center line of maximum crank (journal) eccentricity is pointing to the right. Note that in *(b)* the rotor lobe X has moved only 30 degrees. At the same time, the center line and the eccentric shaft have moved ahead of lobe X as it moves through *(c)*, *(d)*, *(e)*, and *(f)*. In *(f)*, lobe X has moved only 90 degrees from its position at *(a)*. But the center line and the eccentric shaft have turned 270 degrees. When the lobe turns 30 degrees more, to the position X in *(a)*, it will have turned 120 degrees or one-third of a complete revolution of 360 degrees. By the time the rotor makes one complete revolution, the eccentric shaft will have turned three times. There is a 1:3 ratio.

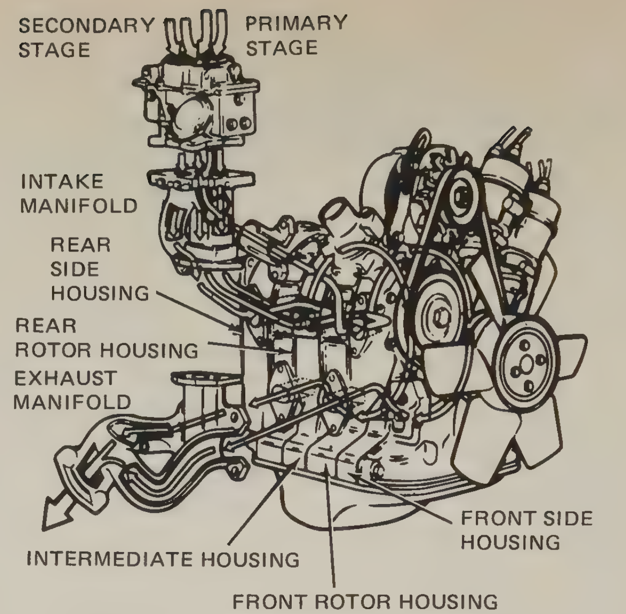


FIG. 13-15 Location of the manifold and carburetor. *(Toyo Kogyo Company, Ltd.)*

○ 13-6 FUEL SYSTEM Figure 13-15 shows the location of the intake manifold and the carburetor on a two-rotor rotary combustion (RC) engine. The carburetor is a four-barrel unit, similar to the four-barrel carburetor used on automobile piston engines. The carburetor has four round channels, or barrels, through which air-fuel mixture can flow to the engine. We discuss carburetors and fuel systems in Chaps. 17 and 18.

The arrows in Fig. 13-16 indicate the paths the air and the air-fuel mixture take on their way to the engine. The primary stage of the carburetor feeds the two rotors through intake ports in the intermediate housing. The primary stage provides the air-fuel mixture for all operating conditions up to medium speed. For acceleration and full-power operation, the secondary stage comes into operation. In Fig. 13-15, note that the secondary stage feeds the air-fuel mixture

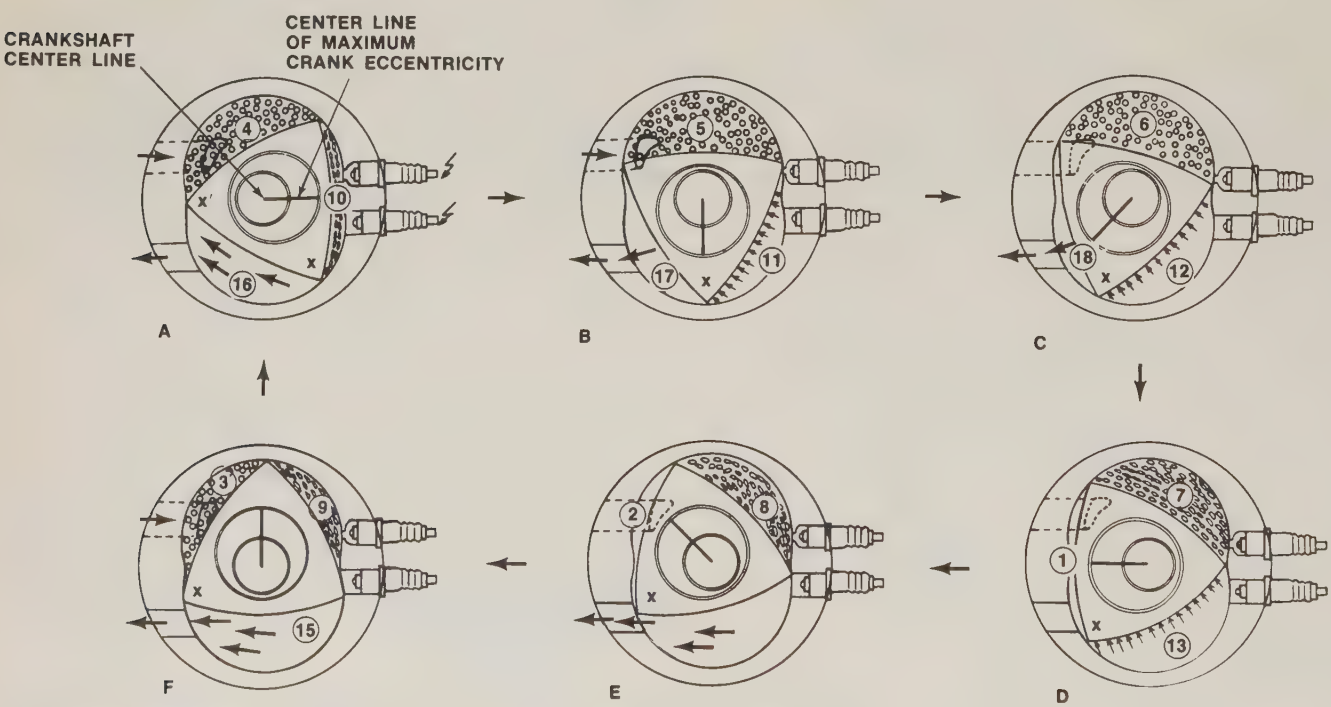


FIG. 13-14 Sequence of actions in the engine. Note how the rotor, as it moves from stage *(a)* to *(f)* and back to *(a)* again, causes the eccentric shaft to rotate one full revolution, or 360 degrees, even though the rotor has turned only 120 degrees. *(Toyo Kogyo Company, Ltd.)*

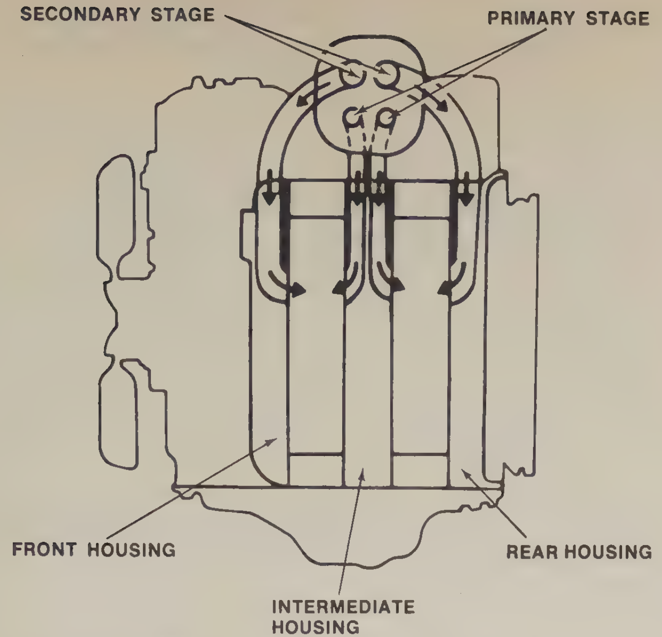


FIG. 13-16 Schematic view of the carburetor. Note how the two carburetor stages supply air-fuel mixture to the intake ports in the three side housings. *(Toyo Kogyo Company, Ltd.)*

through intake ports in the outer side housings. Figure 13-16 is a simplified schematic diagram showing how the two stages of the carburetor work.

○ 13-7 COMPARING WANKEL ENGINE AND PISTON ENGINE The Wankel engine operates on the same four-stroke-cycle as the piston engine: intake, compression, power, and exhaust (as shown in Fig. 13-17). The Wankel engine also has the same ignition, lubricating, fuel, and cooling systems as the piston engine. Many of the components in these systems are very similar, and they are serviced in the same way.

The Wankel engine itself, however, has fewer parts than the piston engine, and it requires fewer service operations. Figure 13-18 shows a comparison between a disassembled six-cylinder piston engine and a two-rotor Wankel engine. The piston engine has 230 basic parts, of which 166 are moving parts. The one-rotor Wankel engine has 70 basic parts, and only three are moving parts. Also, the Wankel engine is about half the size and weight of a conventional piston engine producing comparable horsepower.

REVIEW QUESTIONS

1. How many lobes, or apexes, does the Wankel rotor have?
2. How many chambers are formed by the rotor and the housing?
3. What does "RC" stand for?
4. How many housings does the two-rotor Wankel have?
5. What are the names of the housings in a two-rotor Wankel?
6. How many power thrusts are there for each complete rotor revolution in a Wankel?

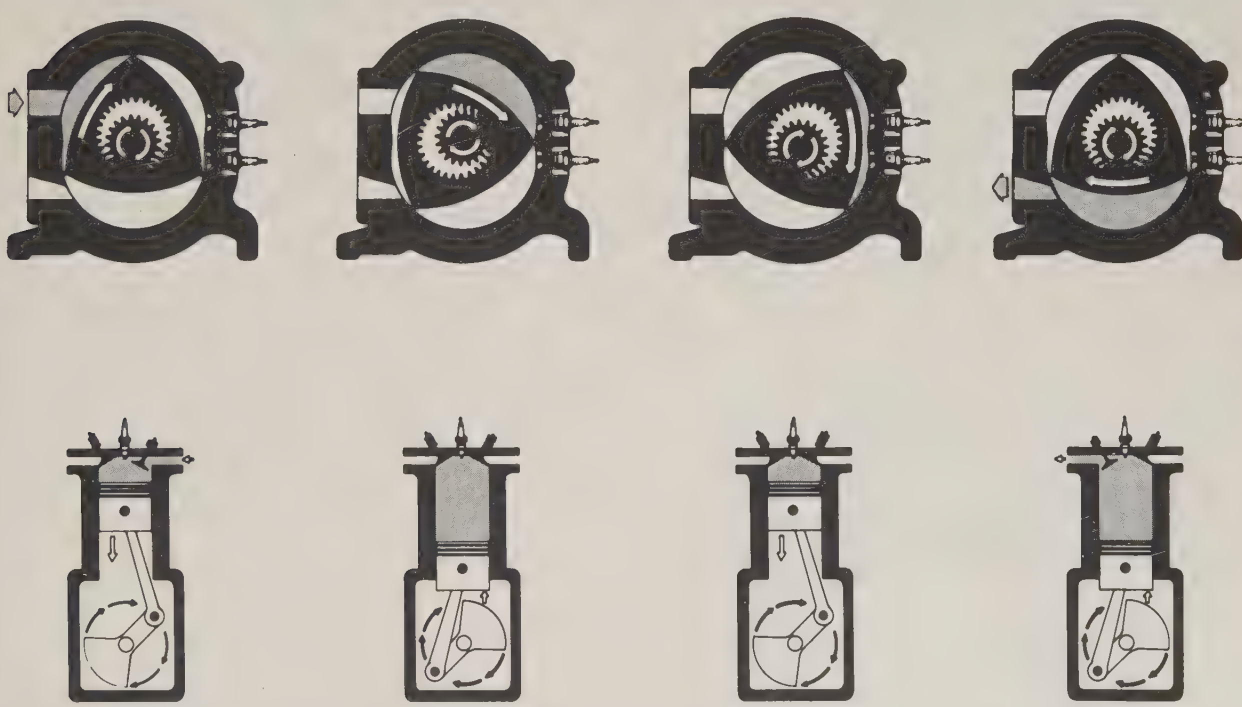
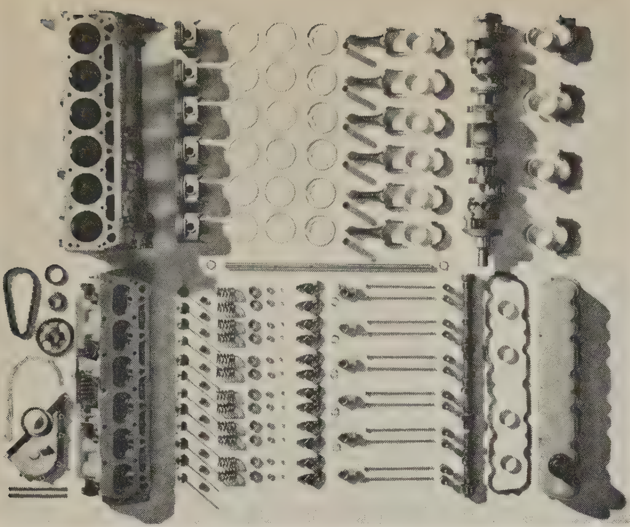
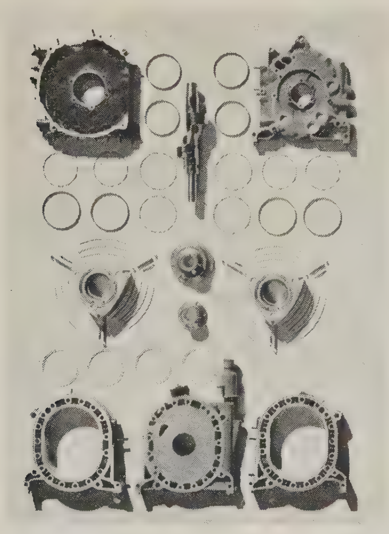


FIG. 13-17 The four strokes of the four-stroke cycle as used in the Wankel engine (top) and in the piston engine (bottom). *(Toyo Kogyo Company, Ltd.)*



SIX-CYLINDER PISTON ENGINE



TWO-ROTOR WANKEL ENGINE

FIG. 13-18 Comparison between a disassembled six-cylinder piston engine (top) and a disassembled two-rotor Wankel engine (bottom). *(Toyo Kogyo Company, Ltd.)*

7. How many times does the eccentric shaft turn as the rotor makes one complete revolution?

8. How many spark plugs does a Mazda two-rotor Wankel engine use?

9. Do all Wankel engines use the same number of spark plugs per rotor?

10. How many barrels does the Mazda two-rotor Wankel-engine carburetor have?

11. In the two-rotor engine, where are the intake ports that are fed by the primary stage of the carburetor?

12. In the two-rotor engine, where are the intake ports that are fed by the secondary stage of the carburetor?

SELF PROJECT

On a sheet of notebook paper, make two columns listing the parts in the Wankel engine and possibly comparable parts in the four-cycle piston engine. Head one column "Wankel Engine," and head the other column "Piston Engine." Start with "rotor" under "Wankel Engine" and with "piston" under "Piston Engine." Then add "eccentric shaft" and "crankshaft." Also "rotor seals" and "piston rings."

The purpose is to compare parts between the two engines. Many of the parts cannot be compared. For example, the piston engine has valves. The Wankel does not. Preparing detailed lists like this will help you understand the similarities and differences between the two engines.

14 Chapter

Engine Measurements

After studying this chapter, you should be able to:

1. **Explain what "bore" and "stroke" mean**
2. **Define "piston displacement" and explain how it is calculated**
3. **Describe compression ratio and how it is calculated**
4. **Define "horsepower," "brake horsepower," "torque," "energy," "power," and "engine efficiency"**
5. **List the various types of friction**

○ 14-1 FUNDAMENTAL MEASUREMENTS Before we get to the actual dimensional and performance measurements of engines, we should look at some fundamentals, such as work, energy, power, torque, and horsepower. This preliminary discussion will give you the background information you need to understand engine measurements.

○ 14-2 WORK *Work* is the moving of an object against an opposing force. The object is moved by a push, a pull, or a lift, as shown in Fig. 14-1. For example, when a weight is lifted, it is moved upward against the pull of gravity. Work is done on the weight. Also, when a coil spring is compressed, work is done on the spring, as shown in Fig. 14-2.

Work is measured in terms of distance and force. If a 5-pound weight is lifted off the ground 1 foot, the amount of work done on the weight is 5 foot-pounds, or 1 foot × 5 pounds. If the 5-pound weight is lifted 2 feet, the amount of work done is 10 foot-pounds. Distance times force equals work.

In the metric system, work is measured in meter-kilograms (mkg). Our example would be as follows: Lifting a 5-kg weight [11 pound] 1 m [3.28 feet] requires 5 mkg of work [36.08 foot-pound]. If the 5-kg weight is lifted 2 m, the amount of work done is 10 mkg [72.16 foot-pound].

○ 14-3 ENERGY Energy is the ability or capacity to do work. When work is done on an object, energy is stored in that object. Lift a 20-pound [9.072 kg] weight 4 feet [1.219 m] and you have stored energy in the weight. The weight can do 80 foot-pounds [11.056 mkg] of work. If a spring is compressed, energy is stored in it, and it can do work as shown in Fig. 14-3.

○ 14-4 POWER Work can be done slowly, or it can be done rapidly. The rate at which work is done is measured in terms of power. A machine that can do a

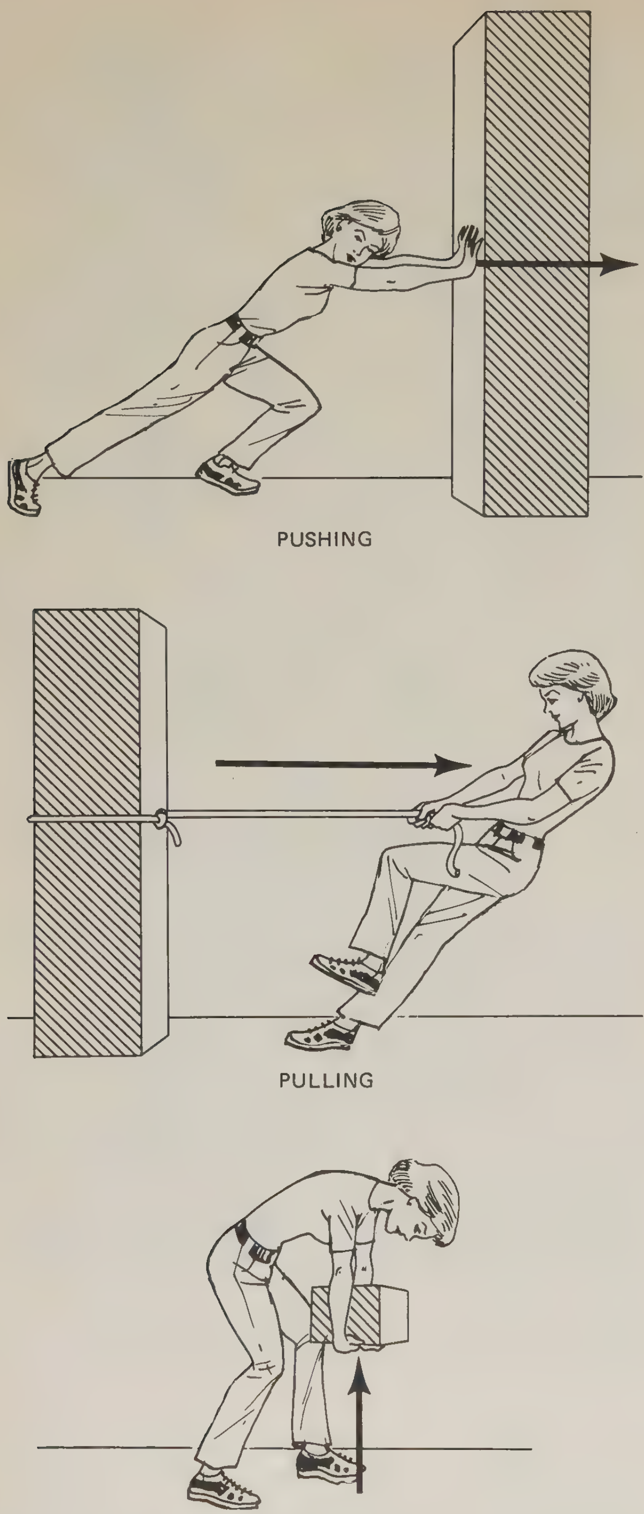


FIG. 14-1 When a push, pull, or lift moves an object, work is done on that object.

great deal of work in a short time is called a high-powered machine. Power is the rate, or speed, at which work is done.

○ 14-5 TORQUE Torque is a twisting, or turning, effort. You apply torque to the top of a screw-top jar when you loosen it, as shown in Fig. 14-4. You apply

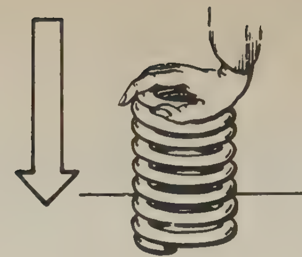


FIG. 14-2 When a spring is compressed, work is done on the spring and energy is stored in it.

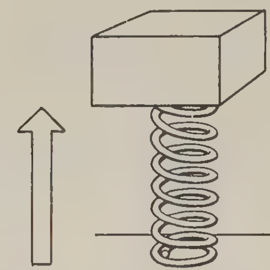


FIG. 14-3 When the spring is released, it can do work on another body. It can lift a weight against gravity, for instance.

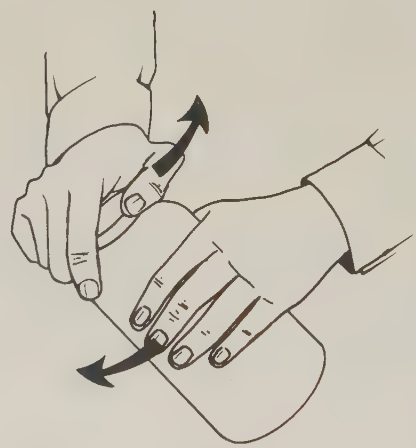


FIG. 14-4 Torque, or twisting effort, must be applied to loosen and remove the top from a screw-top jar.

torque to the steering wheel when you steer a car around a turn. The engine applies torque to the wheels to make them rotate.

However, torque must not be confused with power. Torque is turning effort which may or may not result in motion. Power is something else. It is the rate at which work is being done, and this means that something must be moving.

Torque is measured in pound-feet, not to be confused with foot-pounds of work. In the metric system, torque is measured in kilogram-meters (kgm). For example, suppose you push on a crank with a 20-pound [9.072 kg] push, and the crank is $1\frac{1}{2}$ feet long. You would be applying 30 pound-feet [4.147 kgm] of torque to the crank, as shown in Fig. 14-5. Whether or not the crank was turning, you would be applying

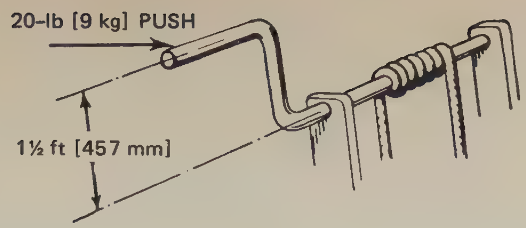


FIG. 14-5 Torque is measured in pound-feet. It is calculated by multiplying the push by the crank offset, or the distance of the push from the rotating shaft.

this torque. The torque is there as long as you continue to apply the 20-pound push to the crank handle.

○ 14-6 HORSEPOWER A horsepower (hp) is the power of one horse, or a measure of the rate at which a horse can work. A 10-hp engine, for example, can do the work of 10 horses.

A horsepower is 33,000 foot-pounds of work per minute. Look at Fig. 14-6. In the illustration, the horse walks 165 feet in 1 minute, lifting the 200-pound weight. The amount of work involved is 33,000 foot-pounds (165 feet × 200 pounds). The time is 1 minute. If the horse did this work in 2 minutes, then it would be only "half" working. It would be putting out only $^1/_2$ hp. One formula for horsepower is

$$\text{hp} = \frac{\text{foot-pounds per minute}}{33{,}000} = \frac{L \times W}{33{,}000 \times t}$$

where hp = horsepower
L = length, in feet, through which W is exerted
W = force in pounds, exerted through distance L
t = time, in minutes, required to move W through L

In the metric system, power output from an engine is often measured in kilowatts (kW). The power output is the amount of electricity the engine could produce if it were used to drive an electric generator. One kilowatt is equal to 1.34 hp, and 1 hp is equal to

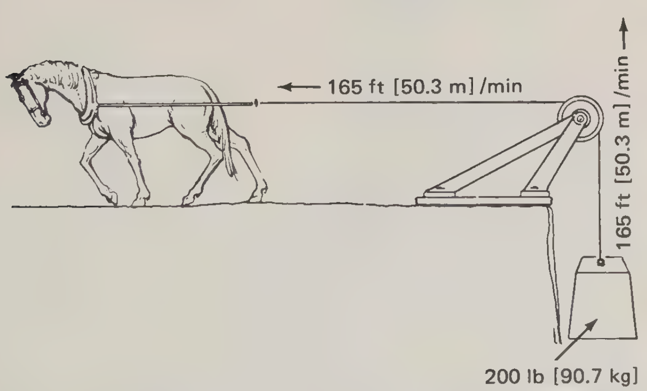


FIG. 14-6 One horse can do 33,000 foot-pounds of work per minute.

0.746 kW. Therefore, a 20-hp engine is equal to a 14.9-kW engine.

Problem: You have a heavy box loaded with sand that you must drag across a level lot for 500 feet in 2 minutes. A pull of 2000 pounds is required to move the box. What horsepower is required?

Solution: Substituting in the formula gives

$$\text{hp} = \frac{L \times W}{33{,}000 \times t} = \frac{500 \times 2000}{33{,}000 \times 2} = 15.15 \text{ hp}$$

A second formula for horsepower, used more often today, is

$$\text{hp} = \frac{\text{torque} \times \text{rpm}}{5252}$$

It is more commonly used because modern dynamometers, described later, measure engine performance in revolutions per minute (rpm), torque, and horsepower. The second formula is easier to work with. Torque was defined earlier.

○ 14-7 INERTIA Inertia is a property of all material objects. It causes them to resist any change in speed or direction of travel. A motionless object tends to remain motionless. A moving object tends to keep moving at the same speed and in the same direction.

Consider the lawn tractor shown in Fig. 14-7. When it is standing still, its inertia must be overcome by applying power to make it move. To increase its

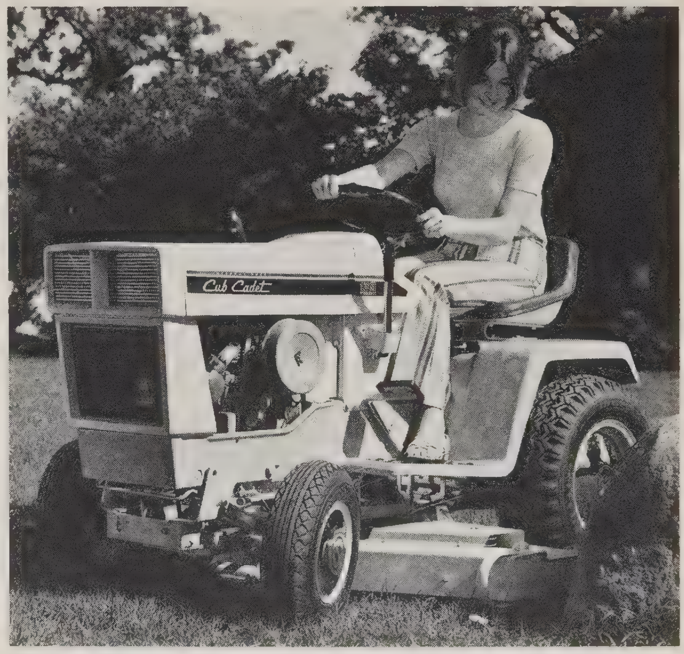


FIG. 14-7 When a lawn tractor is standing still, its inertia must be overcome by applying power to make it move. *(International Harvester Company)*

speed, more power must be applied. To decrease its speed, the brakes must be applied. The brakes must overcome the tractor's inertia to slow it down.

○ 14-8 FRICTION Friction is the resistance to motion between two objects in contact with each other. If you put a book on a table and then pushed the book, you would find that it took a certain amount of push to move it. If you put a second book on top of the first book, you would have to push harder to move the two books on the tabletop. Friction, or resistance to motion, increases with the load. The higher the load, the greater the friction. There are three kinds of friction: dry, greasy, and viscous (Fig. 14-8).

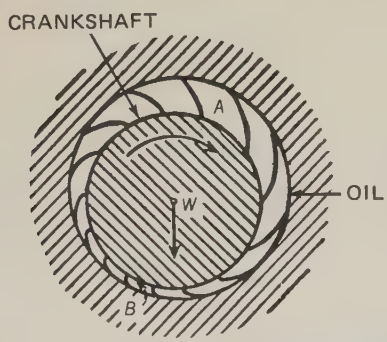


FIG. 14-8 Shaft rotation causes layers of clinging oil to be dragged around with it. This oil moves from the wide clearance A and is wedged into the narrow clearance B, thereby supporting the shaft weight W on an oil film. The clearances are exaggerated in the illustration.

○ 14-9 BUSHINGS AND BEARINGS In the engine, as in almost all machinery, the moving parts are lubricated with oil. Therefore, the surfaces that move against each other are protected against dry friction. These surfaces are specially prepared materials. For example, the cylinder walls against which the pistons and piston rings slide are of smooth gray iron or other metal with good wearing qualities. The cylinder walls in some engines are chrome-plated to improve their resistance to wear. The piston rings are also made of material that gives long life. Shafts are supported by bushings or bearings (see ○ 9-7). Three types of bearing surfaces found in engines are shown in Fig. 14-9.

○ 14-10 ENGINE MECHANICAL MEASUREMENTS We are now ready to discuss engine measurements. First, we will look at the physical measurements: size of the cylinder, distance the piston moves in the cylinder, volume the piston displaces as it moves from BDC to TDC, and so on. Later, we will look into the performance measurements.

○ 14-11 BORE AND STROKE The size of an engine cylinder is given by its bore and stroke. The bore is the diameter of the cylinder. The stroke is the distance the piston travels from BDC (bottom dead center) to TDC (top dead center), as shown in Fig. 14-10. The bore is always mentioned first. For example, in a cylinder 3 by $2^1/_2$ inches, the diameter, or bore, is 3

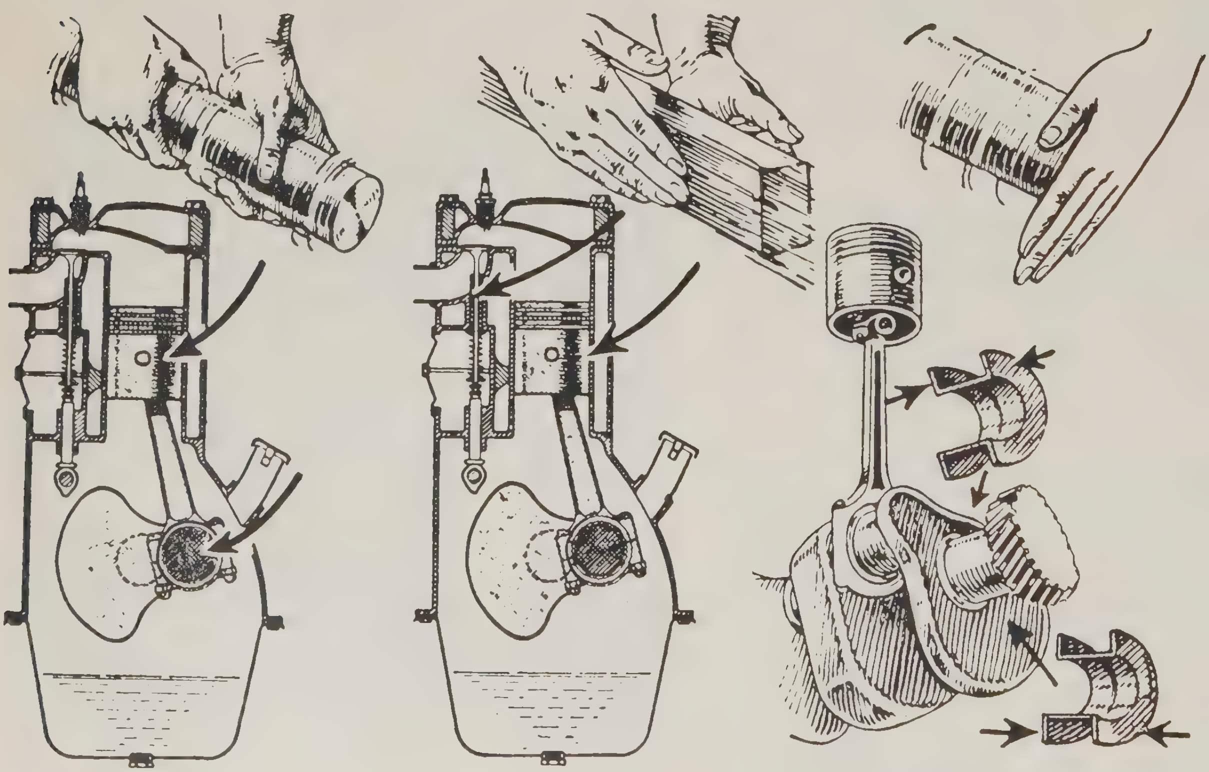


FIG. 14-9 Three types of friction-bearing surfaces in an engine.

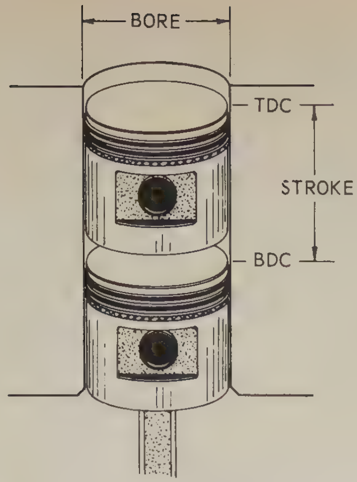


FIG. 14-10 Bore and stroke of an engine cylinder.

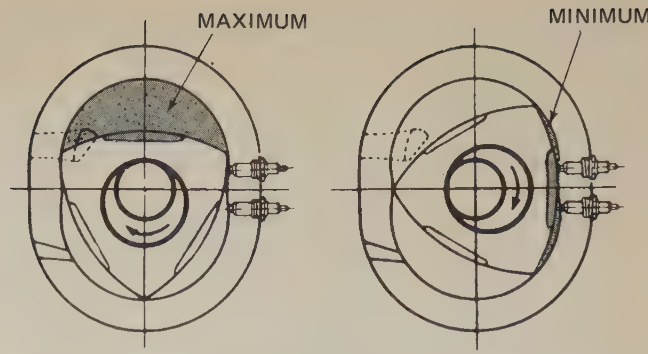


FIG. 14-11 Single-chamber capacity of a Wankel engine.

inches and the stroke is $2\frac{1}{2}$ inches. These measurements are used to figure the piston displacement. Usually, the bore and stroke of a motorcycle engine are given in the metric system in millimeters. A cylinder that is "56 by 50" is a cylinder that has a 56-mm bore.

○ 14-12 PISTON DISPLACEMENT

Piston displacement is the volume that the piston displaces, or "sweeps out," as it moves from BDC to TDC. The piston displacement of a cylinder 3 by 2 inches, for example, is the volume of a cylinder 3 inches in diameter and 2 inches long. Piston displacement in one cylinder of an engine is equal to

$$\begin{aligned} \tfrac{1}{4}\,\pi \times D^2 \times L &= 0.7854 \times 3^2 \times 2 \\ &= 0.7854 \times 9 \times 2 \\ &= 14.14 \text{ cubic inches} \end{aligned}$$

where π = 3.1416, a constant used to find the area of a circle
D = diameter, or bore, of cylinder
L = length of stroke

If the engine has four cylinders, the total displacement is 14.14 times 4, or 56.56 cubic inches.

In the metric system, displacement is given in cubic centimeters (cc). Therefore, a 56.56-cubic-inch displacement would be 927 cc in metric measurements. And, since 1000 cc equals 1 liter (L), 927 cc is 0.927 L.

The Wankel engine does not have pistons, so you cannot figure piston displacement on the Wankel. But you can figure the displacement the rotor produces as the volume in the combustion chamber goes from maximum to minimum, as shown in Fig. 14-11. For example, suppose the volume is reduced 490 cc as it goes from maximum to minimum. This is the displacement in one of the three chambers of the rotor. Instead of using the term "piston displacement," this figure is called *single-chamber capacity*.

○ 14-13 COMPRESSION RATIO

The compression ratio of an engine is a measure of how much the air-fuel mixture is compressed in an engine cylinder. It is calculated by dividing the air volume in one cylinder with the piston at BDC by the air volume with the piston at TDC, as shown in Fig. 14-12. The air volume with the piston at TDC is called the clearance volume. It is the clearance that remains above the piston at TDC.

Let us look at an example of compression-ratio calculation: One cylinder of an engine has a volume of 42.35 cubic inches [694 cc] at BDC, as shown in Fig. 14-12*a*. It has a clearance volume of 4.45 cubic inches [73 cc], as shown in Fig. 14-12*b*. The compression ratio is 42.35 divided by 4.45 [694 ÷ 73], or 9.5 : 1 [9.5 : 1]. During the compression stroke, the air-fuel mixture is compressed from a volume of 42.35 cubic inches [694 cc] to 4.45 cubic inches [73 cc], or to 1/9.5 of its original volume.

○ 14-14 ENGINE PERFORMANCE MEASUREMENTS

Let us now look at the measurements that can be taken on an operating engine. There are several interrelated factors, including volumetric efficiency, horsepower, friction horsepower, and torque.

○ 14-15 VOLUMETRIC EFFICIENCY

The amount of air-fuel mixture taken into the cylinder on the intake stroke is a measure of the engine's volumetric

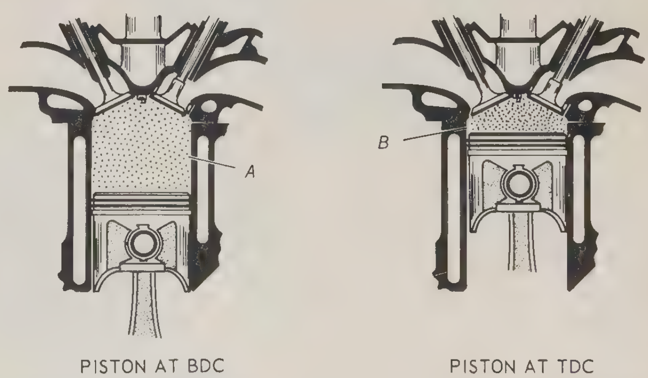


FIG. 14-12 Compression ratio is the volume in a cylinder with the piston at BDC divided by its volume with the piston at TDC, or A divided by B.

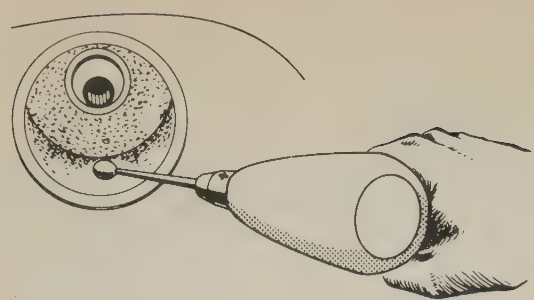


FIG. 14-13 Smoothing the inside surfaces of the intake ports improves volumetric efficiency of an engine.

efficiency. If the mixture were drawn into the cylinder slowly, a full charge of air-fuel mixture could get in. But the mixture must pass rapidly through narrow openings and bends in the carburetor and intake passages. In addition, the mixture is heated from engine heat. Therefore, the mixture expands. The rapid movement and heating reduce the amount of mixture that can get into the cylinder. A full charge of air-fuel mixture cannot enter, because the time is too short and the air is heated.

Volumetric efficiency is the ratio of the amount of air-fuel mixture that actually enters the cylinder to the amount that could possibly enter. For example, a certain cylinder has an air volume, as shown in Fig. 14-12a, of 4.7 cubic inches [770 cc]. If the cylinder were allowed to completely "fill up," it would take in 0.034 ounce [0.964 g] of air. However, suppose that the engine is running at a high speed, and so only 0.027 ounce [0.765 g] of air can enter during each intake stroke. This means that the volumetric efficiency is only about 80 percent (0.027 is 80 percent of 0.034). Actually, 80 percent is a good volumetric efficiency for an engine running at fairly high speed. The volumetric efficiency of some engines may drop to as low as 50 percent at high speeds. This is another way of saying that the cylinders are only "half-filled" at high speeds.

Volumetric efficiency also can be increased by making the intake ports and passages wider and as straight and as short as possible. Also, the smoothness of the inside surfaces of the intake ports is important. Rough surfaces which slow down the flow of air-fuel mixture can be smoothed as shown in Fig. 14-13. Another way to improve volumetric efficiency is to use more carburetors or use carburetors with larger air passages, which improve engine breathing at high speed. All these changes help produce more power by improving volumetric efficiency.

○ 14-16 BRAKE HORSEPOWER The horsepower (hp) output of engines is measured in terms of brake horsepower (bhp). The name comes from the braking device that is used to hold engine speed down while torque or hp is measured, as shown in Fig. 14-14. When an engine is rated at 30 hp [22.38 kW], for example, it is really bhp that is meant. This is the amount of power the engine has available to do work at the flywheel or crankshaft at a certain speed at wide-open throttle.

The usual way to rate an engine is with a dynamometer. This device has a mechanism (an electric generator, water brake, or friction brake) which can put different loads on the engine. The dynamometer

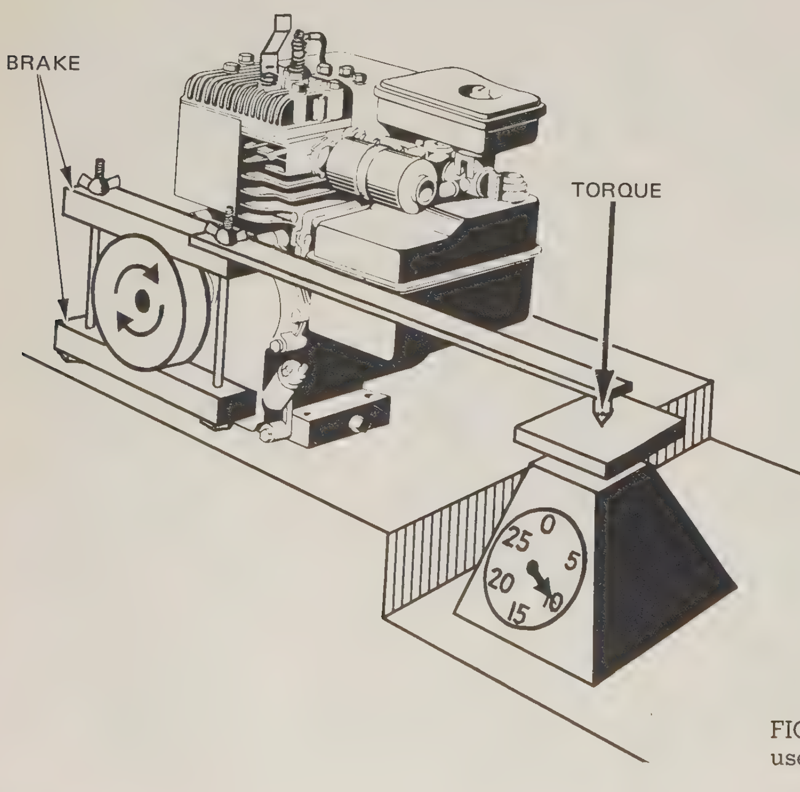


FIG. 14-14 A small-engine dynamometer which can be used to measure engine torque and brake horsepower.

measures the amount of hp the engine can develop under various operating conditions.

Some dynamometers are used to test engines by themselves. This type of dynamometer is known as an engine dynamometer and is shown in Fig. 14-14. The dynamometer used in the service shop checks the engine in the car or in the frame of the motorcycle. This type of unit is called a chassis dynamometer. The drive wheels of the vehicle are placed on rollers. The engine drives the wheels, and the wheels drive the rollers. The rollers can be loaded, or braked, varying amounts so that engine output can be measured.

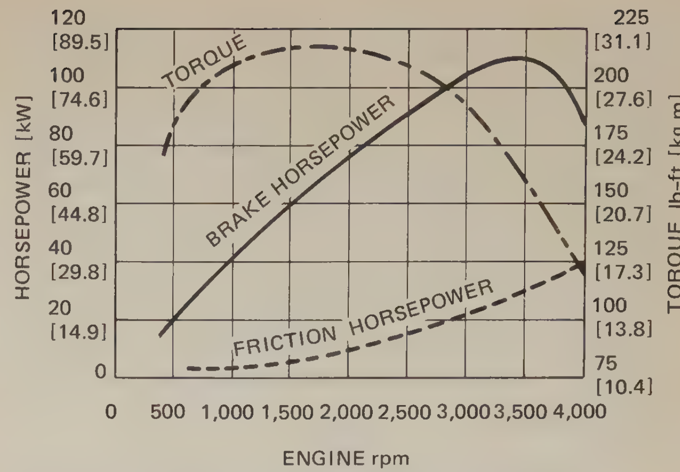


FIG. 14-16 Torque-bhp-fhp curves of an engine.

○ 14-17 INDICATED HORSEPOWER Indicated horsepower (ihp) is the power that the engine develops inside the combustion chambers during the combustion process. A special device is required to measure ihp. It measures the pressures in the engine cylinders. The four small drawings in Fig. 14-15 show the four piston strokes, and the curve shows the pressures in the cylinder during these four strokes. These pressures are used to figure ihp. Indicated horsepower is above bhp, because some of the power developed in the engine cylinders is used up to overcome friction.

○ 14-18 FRICTION HORSEPOWER (fhp) Friction horsepower (fhp) is the power required to overcome the friction of the moving parts in the engine. One of the major causes of friction loss (or fhp) is piston-ring friction. Under some conditions, the friction of the rings moving on the cylinder walls accounts for 75 percent of all friction losses in the engine. This points up one advantage of the short stroke oversquare engine. With a short stroke, the piston rings do not have as far to move. Therefore, ring friction is lower. Figure 14-16 shows a curve of fhp for one engine operating under certain specified conditions.

○ 14-19 RELATING bhp, ihp AND fhp We have learned that bhp is the power delivered, ihp is the power developed in the engine, and fhp is the power lost through friction. The relationship among the three is

$$\text{bhp} = \text{ihp} - \text{fhp}$$

The horsepower delivered by the engine (bhp) is equal to the horsepower developed (ihp) minus the power lost through friction (fhp).

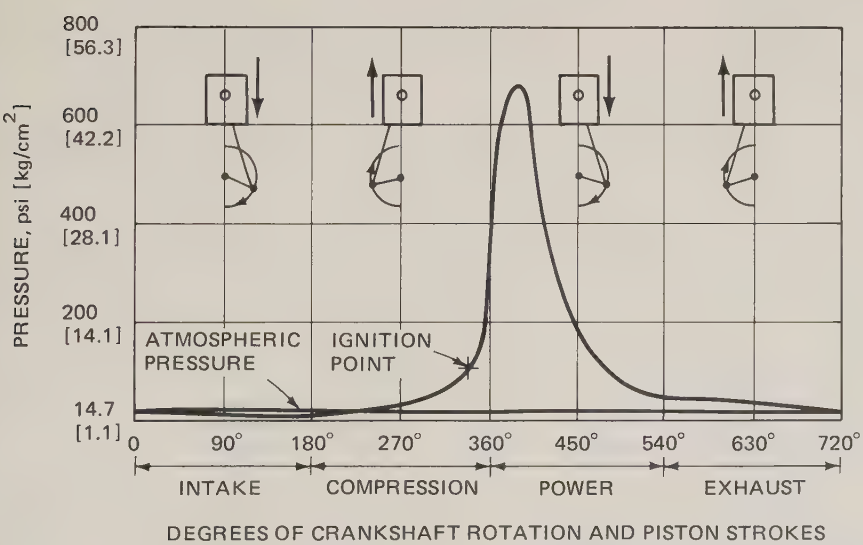


FIG. 14-15 Pressures in an engine cylinder during the four piston strokes. The four strokes require two crankshaft revolutions (360 degrees each), a total of 720 degrees of rotation. This curve is for a particular engine operating at one definite speed and throttle opening. Changing the speed and throttle opening would change the curve (particularly the power curve).

○ 14-20 ENGINE TORQUE Torque is turning effort (see ○ 14-5). When the piston is moving down on the power stroke, it applies torque to the engine crankshaft through the connecting rod. The harder the push on the piston, the greater the torque applied. The higher the combustion pressures, the greater the amount of torque.

The dynamometer is normally used to check engine torque. Engine dynamometers frequently have direct-reading torque meters. Chassis dynamometers may have direct-reading hp meters. To find the hp of an engine when the meter on the dynamometer indicates torque, use the formula discussed in ○ 14-6.

○ 14-21 BRAKE HORSEPOWER VERSUS TORQUE The torque that an engine can develop changes with engine speed, as shown in Fig. 14-16. During intermediate speeds, volumetric efficiency is high. There is sufficient time for the cylinders to become fairly well "filled up." This means that with a fairly full charge of air-fuel mixture, higher combustion pressures will develop. With higher combustion pressures, the engine torque is higher.

At higher speed, volumetric efficiency drops off. There is not enough time for the cylinders to become filled up with air-fuel mixture. Since there is less air-fuel mixture to burn, the combustion pressures do not go as high. There is less push on the pistons, and engine torque is lower. Note in Fig. 14-16 how the torque drops off as engine speed increases.

The bhp curve of an engine is different from the torque curve. In Fig. 14-16, the curves start at low speed and increase until a high engine speed is reached. Then, at still higher speeds, bhp drops off.

The drop-off of bhp is due to reduced torque at higher speed. Figure 14-16 compares the curves of torque, bhp, and fhp for a car engine. Figure 14-17 compares the torque and bhp curves for a two-cylinder 24-hp engine.

Note that the curves in Figs. 14-16 and 14-17 are for two particular engines only. Different engines have different torque, bhp, and fhp curves. Peaks may be at higher or lower speeds, and the relationships may not be as shown in the curves.

○ 14-22 ENGINE EFFICIENCY The term "efficiency" relates the effort exerted and the results obtained. For engines, efficiency is the relation between the power delivered and the power that could be obtained if the engine operated without any power loss. Engine efficiency can be computed in two ways: as mechanical efficiency and as thermal efficiency.

1. *Mechanical Efficiency.* This is the relationship between bhp and ihp. It can be written as follows:

$$\text{Mechanical efficiency} = \frac{\text{bhp}}{\text{ihp}}$$

   Example: At a certain speed, the bhp of an engine is 116 and its ihp is 135. Mechanical efficiency is bhp/ihp = 116/135 = 0.86, or 86 percent. This means that 86 percent of the power developed in the cylinders is delivered by the engine. The remaining 14 percent, or 19 hp [14.17 kW], is consumed as fhp.

2. *Thermal Efficiency. Thermal* means "of or related to heat." The thermal efficiency of an engine is the relation between the power output and the energy in the fuel burned to produce this output.

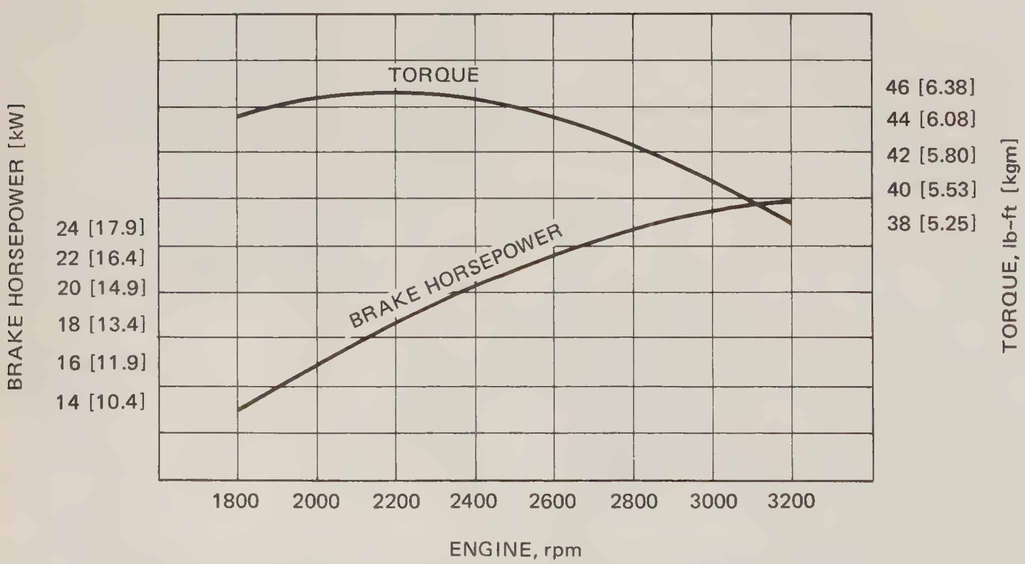


FIG. 14-17 Brake horsepower and torque curves of an opposed-cylinder two-cylinder engine rated at 24 hp [18 kW]. *(Kohler Company)*

Some of the heat produced by combustion is carried away by the engine cooling system. Some of it is lost in the exhaust gases, which are hot when they leave the cylinder. These are heat (thermal) losses that reduce the thermal efficiency of the engine. They do not add to the power output of the engine. The remainder of the heat is used by the engine to develop power. Because a great deal of heat is lost during engine operation, thermal efficiencies may be as low as 20 percent. They are seldom higher than 25 percent.

REVIEW QUESTIONS

1. Define "work." In what terms is it measured?
2. Define "energy."
3. Define "power."
4. Define "horsepower." In what terms is horsepower measured in the United States Customary System? In the metric system?
5. An engine develops 20 pound-feet of torque at 2000 rpm. What is the horsepower?
6. What are the three kinds of friction? Define each.
7. What are the bore and stroke of an engine? How are bore and stroke given in the metric system?
8. What is piston displacement? In what terms is the piston displacement given in the metric system? How many cubic inches displacement does a 2-L engine have?
9. What does the term "single-chamber displacement" mean?
10. Define "volumetric efficiency."
11. Explain what can be done to the valves and intake passages to improve volumetric efficiency.
12. Will a one-barrel or a two-barrel carburetor give better volumetric efficiency? Why?
13. What is brake horsepower? How is it measured in the shop?
14. What is compression ratio? How can it be increased in an engine?
15. What is ihp?
16. What is fhp? What is the major cause of fhp in an engine?
17. What is the relationship among bhp, ihp, and fhp?
18. What is mechanical efficiency?
19. What is thermal efficiency?
20. What is inertia?

SELF PROJECT

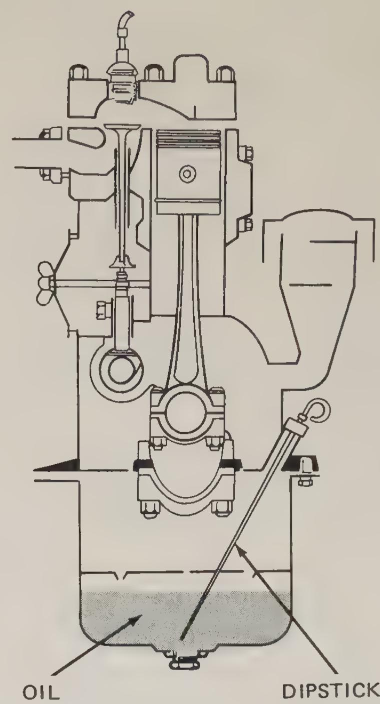
At the top of a sheet of notebook paper write down "Finding Dynamometer Horsepower." Then write down the second formula for hp given in ○ 14-6. This formula calls for only torque and rpm. Now look up these two figures in manufacturers' service manuals. Then work out the hp ratings, using the formula. These are the ratings you would find if you tested the engines on the dynamometer and the engines were in good condition.

The hp ratings based on torque and rpm may be different from the hp ratings the engine manufacturers advertise. And the rpms may be different also.

three ENGINE SYSTEMS

Part 3 of the *Small-Engine Mechanics* describes the construction, operation, and servicing of the systems in a small engine which are needed to make the engine run. These include fuel systems, lubricating systems, and cooling systems. Electrical systems are covered in Part Four.

There are five chapters in Part Three. These are as follows:



15 Chapter

Engine Lubrication

After studying this chapter, you should be able to:

1. **Explain how a two-cycle engine is lubricated and how a four-cycle engine is lubricated**
2. **Describe how to prepare premix**
3. **List the purposes of lubricating oil in the engine**
4. **Explain how engine oil is rated as to viscosity and service**
5. **Discuss the difference between the requirements for oils used in two-cycle engines and those for oils used in four-cycle engines**
6. **Describe the components in the engine lubricating system and how each works**

○ 15-1 TWO-CYCLE- AND FOUR-CYCLE-ENGINE LUBRICATION In this chapter we look at the ways in which two-cycle and four-cycle engines are lubricated. In the two-cycle engine, the oil is mixed with the gasoline. The oil enters the engine along with the air-fuel mixture and lubricates the engine. In the four-cycle engine, there is a supply of oil in the lower part of the crankcase. When the engine is running, oil from this reserve supply is either pumped or splashed on all moving parts in the engine. In either type of engine, the result is that the engine parts get the lubrication they need so that minimum friction and wear result.

○ 15-2 LUBRICATING THE ENGINE When a four-cycle engine needs oil, the oil is poured into a pipe or opening in the valve cover or on the side on the engine, as shown in Fig. 15-1. From there the oil runs down into the lower part of the engine which is called the crankcase. The crankcase in the four-cycle engine usually is the reservoir from which the engine lubricating system sends oil to all moving engine parts. However, in some four-cycle motorcycle engines, the oil reservoir is a separate oil tank. This arrangement is called a dry-sump lubricating system and is discussed in a later section.

In the two-cycle engine, adding oil to the crankcase would not work. If the oil were kept in the crankcase of a two-cycle engine, the incoming air-fuel mixture (which passes through the crankcase) would pick up some of the oil and carry it into the cylinder. There, the oil would be burned. Soon all the oil would be consumed, and the engine then would fail from lack of oil.

Other lubricating procedures are used in two-cycle engines. One method, called *premixing,* is to mix a little lubricating oil with the gasoline (Fig. 15-2). Then the oil enters the crankcase along with the air-fuel mixture as a fine mist. Some of the oil mist is carried to the engine cylinder, where most of it is burned. But

FIG. 15-1 When a four-cycle engine needs oil, the oil is poured into an opening in the engine. *(Briggs & Stratton Corporation)*

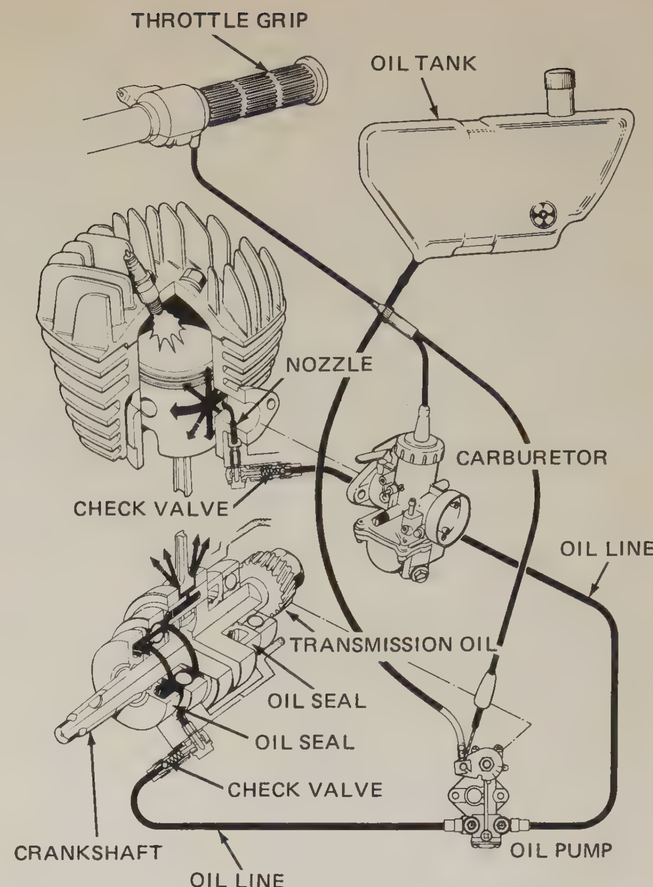


FIG. 15-3 Lubrication system for a one-cylinder two-cycle motorcycle engine. *(Suzuki Motor Company, Ltd.)*

part of the oil gets on the cylinder wall and engine bearings to provide adequate lubrication. The amount of oil to be added to the gasoline varies with the engine. Some engines require only 1 or 2 fluid ounces [30 or 60 cc] per gallon of gasoline. Other engines require 1 quart [0.946 L] of oil to be mixed with every 5 gallons [18.927 L] of gasoline. The instructions of the engine manufacturer should always be followed when oil is mixed with gasoline for use in a two-cycle engine.

A second method of lubricating a two-cycle engine uses a separate oil tank. Figure 15-3 shows this system, called the *oil-injection system,* on a one-cylinder two-cycle motorcycle engine. Oil from the tank is sent by the pump to the nozzle in the intake port. There the amount of oil needed by the engine sprays out into the passing air-fuel mixture. On some engines, this is all the lubrication that the engine receives. In operation, the system is little different from the mixing achieved by the use of a premix, or a mixture of gasoline and oil, in the fuel tank. However, in Fig. 15-3, a second oil line from the pump also provides full-pressure lubrication to the crankshaft and bearings. Here is how the system works:

Oil from the tank is sent to the engine moving parts by the oil pump. The oil flows through two oil lines. One oil line sends the oil to the nozzle in the intake port in back of the carburetor. The oil sprays from the nozzle into the air-fuel mixture going into the engine. This provides lubrication of the piston, piston rings, piston pin, and cylinder wall. A second oil line sends oil to the crankshaft to lubricate the main and connecting-rod big-end bearing. In the oil-injection system shown in Fig. 15-3, the amount of oil pumped to the intake port and bearings changes with engine speed and throttle opening. As a result, the engine gets the right amount of oil it needs for every operating condition. We will describe these various lubricating systems in detail later. First, let us find out about the properties of lubricating oil.

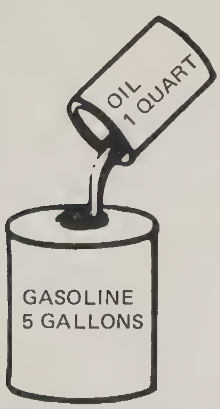


FIG. 15-2 To lubricate most two-cycle engines, the lubricating oil is mixed with the gasoline.

○ 15-3 PURPOSE OF LUBRICATING OIL We normally think of lubricating oil as a liquid that minimizes friction and wear between moving parts in a machine. However, the lubricating oil does several other things in the engine. The lubricating oil must perform these jobs:

1. Lubricate moving parts to minimize wear
2. Lubricate moving parts to minimize power loss from friction
3. Remove heat from engine parts by acting as a cooling agent

4. Absorb shocks between bearings and other engine parts, thereby reducing engine noise and extending engine life
5. Form a good seal between piston rings and cylinder walls
6. Act as a cleaning agent

○ 15-4 MINIMIZING WEAR AND POWER LOSS FROM FRICTION Friction has been discussed in some detail in ○ 14-8. The type of friction in the engine is normally viscous friction. It is the friction between adjacent moving layers of oil. If the lubricating system does not function properly, sufficient oil will not be supplied to moving parts, and greasy or even dry friction will result between moving surfaces. This would cause, at least, considerable power loss, since power would be used in overcoming these types of friction. At most, major damage would occur to engine parts as greasy or dry friction developed. Bearings would wear rapidly. The heat resulting from dry or greasy friction would cause bearing disintegration and failure, and so connecting rods and other parts would be broken. Also, insufficient lubrication of cylinder walls would cause rapid wear and scoring of walls, rings, and pistons. A properly operating four-cycle engine lubricating system supplies all moving parts with sufficient oil so that only viscous friction is obtained. In the two-cycle engine using a fuel-oil mix, adding the proper amount of oil to the gasoline assures adequate engine lubrication.

○ 15-5 REMOVING HEAT FROM ENGINE PARTS In the four-cycle engine, the oil is in rapid circulation throughout the engine lubricating system. All bearings and moving parts are bathed in streams of oil. In addition to providing lubrication in the four-cycle engine, the oil absorbs heat from engine parts and carries it back into the oil pan. The oil pan in turn absorbs heat from the oil, transferring it to the surrounding air. In this way the oil acts as a cooling agent.

○ 15-6 ABSORBING SHOCKS BETWEEN BEARINGS AND OTHER ENGINE PARTS As the piston approaches the end of the compression stroke and the mixture in the cylinder is ignited, pressure in the cylinder suddenly increases many times. A load of as much as 2000 pounds [907 kg] is suddenly imposed on the top of the piston as combustion takes place. This sudden increase in pressure causes the piston to thrust down hard through the piston-pin bearing, connecting rod, and connecting-rod bearing. There is always some space, or clearance, between bearings and journals. This space is filled with oil. When the load suddenly increases as described above, the layers of oil between bearings and journals must act as cushions, resisting penetration or "squeezing out," and must continue to interpose a film of oil between the adjacent metal surfaces. By absorbing and cushioning the hammerlike effect of the suddenly imposed loads, the oil quiets the engine and reduces wear of parts.

○ 15-7 FORMING A SEAL BETWEEN PISTON RINGS AND CYLINDER WALLS Piston rings must form a gastight seal with the cylinder walls. The lubricating oil that is delivered to the cylinder wall helps the piston rings accomplish this. The oil film on the cylinder walls compensates for microscopic irregularities in the fit between the rings and walls and fills in any gaps through which gas might escape. The oil film also provides lubrication of the rings so that they can move easily in the ring grooves and on the cylinder walls.

○ 15-8 ENGINE OIL Before we explain the lubricating system, let us take a look at oil for four-cycle engines. Oil is the liquid used in the lubricating system. For many years, the only oil used in engines was made from natural crude oil, which comes from oil wells drilled deep into the earth. Much of the engine oil used today still comes from crude oil. This crude oil was formed underground millions of years ago in various parts of the world. It must be refined to make it usable. In the refining process, gasoline, kerosene, lubricating oil, and many other products are made.

In recent years, synthetic oils have come out of the chemical laboratory. The manufacturers claim that these have superior lubricating properties. Actually, there are three basic types of synthetic oils. The type most widely used at present is produced from organic acids and alcohols (from plants of various types). A second type is produced from coal and crude oil. A third type is made from crude oil. Although tests have shown these synthetics to have certain superior properties, no engine manufacturer has given them unqualified approval yet.

Not all oil is the same. There are several grades of oil and several ratings. Oil made for engines contains a number of additives (chemical compounds that are added to the oil) that improve the performance of the oil.

○ 15-9 PROPERTIES OF OIL A satisfactory engine lubricating oil for four-cycle engines must have certain characteristics, or properties. It must have proper viscosity and must resist oxidation, carbon formation, corrosion, rust, extreme pressure, and foaming. Also it must act as a good cleaning agent, must pour at low temperatures, and must have good viscosity at extremes of high and low temperature.

Any mineral oil, by itself, does not have all these properties. Lubricating-oil manufacturers therefore

put a number of additives into the oil during the manufacturing process. An oil for severe service may have many or all of the following additives:

1. Viscosity improver
2. Pour-point depressants
3. Inhibitors
4. Detergent dispersants
5. Extreme-pressure compounds

These are discussed in the following sections.

○ 15-10 OIL VISCOSITY AND SERVICE RATINGS "Viscosity" refers to the ability of a liquid to flow. An oil with high viscosity is very thick and flows slowly. An oil with low viscosity flows easily. Oil gets thicker as it becomes colder. Therefore, starting an engine in cold weather is more difficult than starting it in warm weather. The cold has increased the viscosity of the oil.

Oil viscosity is rated in two ways by the Society of Automotive Engineers (SAE). It is rated for (1) winter driving and (2) summer driving. Winter-grade oils come in three grades: SAE 5W, SAE 10W, and SAE 20W. The "W" stands for winter grade. For other than winter use, the grades are SAE 20, SAE 30, SAE 40, and SAE 50. The higher the number, the higher the viscosity (the thicker the oil). All these grades are called single-viscosity oils.

Many oils have multiple-viscosity ratings. For example, SAE 10W-30 has the same viscosity as SAE 10W when it is cold and the same viscosity as SAE 30 when it is hot.

The engine manufacturer specifies the viscosity of oil for the engine. Figure 15-4 shows how outside temperature affects the viscosity of oil that an engine needs. If you study the table, you will see that the higher the outside temperature, the higher the viscosity rating specified. The 5W-30 oil is good for starting and operating in very low outside temperatures. The 10W-30 or 10W-40 oil will not thin out too much as the temperature rises.

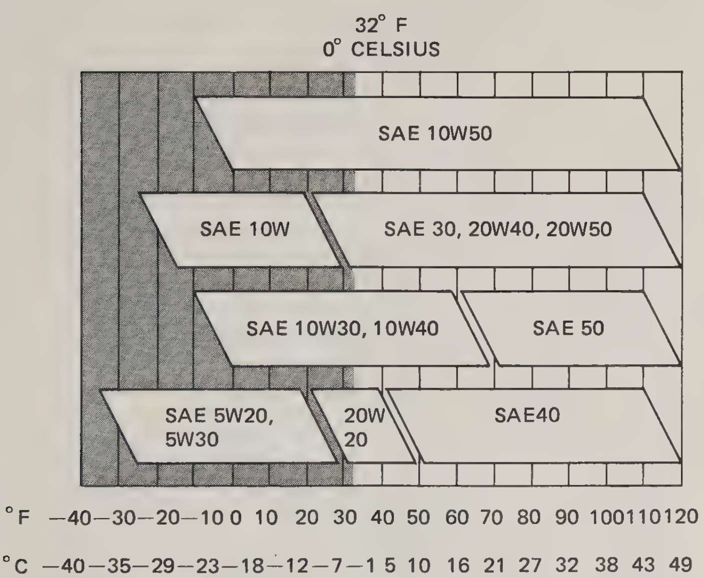


FIG. 15-4 Oil viscosity recommendations for Onan four-cycle air-cooled engines. *(Onan Corporation)*

The service rating indicates the type of service for which the oil is best suited. For gasoline engines, the service ratings are SA, SB, SC, SD, and SE. Here is a brief description of each of these ratings:

- SA—Acceptable for engines operated under the mildest conditions
- SB—Acceptable for minimum-duty engines operated under mild conditions
- SC—Meets requirements of gasoline engines in 1964–1967 model passenger cars and some trucks
- SD—Meets requirements of gasoline engines in 1968–1970 model passenger cars and some trucks
- SE—Meets requirements of gasoline engines in 1972 and later cars and certain 1971 model passenger cars and trucks

You will notice that this is an open-end series. When the engine manufacturers and oil producers see the need for other types of oil, they can bring out SF and SG service-rated oils.

Diesel engines require different types of oil. They are service-rated CA, CB, CC, and CD. CD is for diesel-engine operations under the most severe conditions.

○ 15-11 OIL ADDITIVES Certain chemical compounds, called additives, are added to the oil. The purpose of these additives is to give the oil certain properties it does not have in its original refined state. The refining process determines the viscosity and other basic properties of the oil. The additives give the oil other desirable properties. These additives include viscosity improver, pour-point depressants, inhibitors, detergent dispersants, and extreme-pressure compounds.

○ 15-12 TWO-CYCLE ENGINE OIL Two-cycle engines use a "total-loss" lubrication system. The oil is not recovered as in four-cycle engines but is burned in the combustion chamber. For this reason, the lubricating oil used in two-cycle engines does not necessarily require all the additives listed in previous sections. But the oil must be clean-burning and leave a minimum of ash and carbon. Special oils have been developed for two-cycle and outboard engines. Outboard engine manufacturers, for example, recom-

mend a BIA TC-W oil. *BIA* means *B*oating *I*ndustry *A*ssociation, and *TC-W* means *T*wo-*C*ycle *W*ater-cooled. Outboard engine manufacturers caution against using automotive oils, which can produce ash and cause engine trouble. There also are special oils for small engines. Always use the oil recommended by the engine manufacturer, and follow the directions on the oil container.

○ 15-13 SLUDGE FORMATION IN FOUR-CYCLE ENGINES Sludge is a thick creamy black substance that often forms in the crankcase of four-cycle engines. It clogs oil screens and oil lines, preventing normal circulation of lubricating oil to engine parts. This can result in engine failure from oil starvation.

Water collects in the crankcase in two ways: First, water is formed as a product of combustion. Second, the crankcase ventilating system carries air, with moisture in it, through the crankcase. If the engine parts are cold, the water condenses and drops into the crankcase. There, the water is churned up with the lubricating oil by the action of the crankshaft. The crankshaft acts much like a giant eggbeater and whips the oil and water into the thick, black, mayonnaise-like "goo" known as sludge. The black color comes from dirt and carbon.

○ 15-14 OIL CHANGES FOR FOUR-CYCLE ENGINES From the day that fresh oil is put into the engine crankcase (four-cycle engines), the oil begins to lose effectiveness as an engine lubricant. This gradual loss of effectiveness is largely due to the accumulation of various contaminating substances.

The oil should be changed at recommended intervals. In automotive engines, this might be every two months or 6000 miles [9656 kilometers (km)], whichever comes first. For small four-cycle engines, many manufacturers recommend oil changes every 25 hours of operation. Engines in power mowers and other such equipment often operate in unusually dusty conditions. The oil must be changed frequently to prevent heavy accumulations of dirt in the oil that could cause rapid engine wear. Always follow the engine manufacturer's recommendations printed on the nameplate or listed on the lubricating-instructions decal. A typical decal is shown in Fig. 15-5. It is attached to the engine or to the equipment in which the engine is installed.

○ 15-15 FOUR-CYCLE ENGINE LUBRICATING SYSTEMS The two-cycle engine uses a "total-loss" lubricating system. The oil is not recovered and reused. When it goes into the engine, it is burned along with the fuel. However, the four-cycle engine has a reservoir of engine lubricating oil which recirculates constantly through the engine. In some engines, the oil pump continuously sends oil from the oil pan through lines to all moving engine parts. The oil then drops back down into the oil pan.

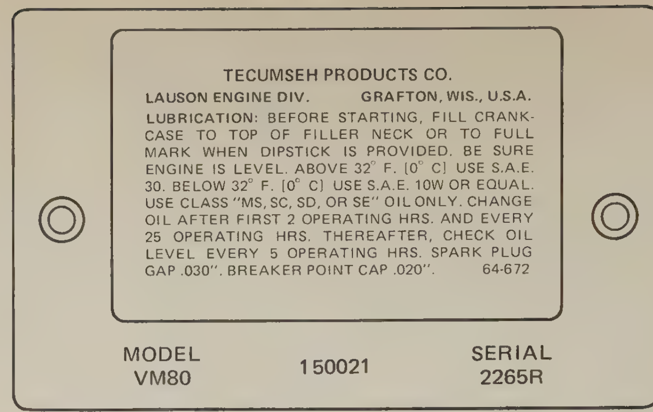


FIG. 15-5 Decal with lubricating instructions on a four-cycle engine. *(Tecumseh Products Company)*

There are two types of lubricating systems for four-cycle engines: the dry-sump and the wet-sump. We will now look at both of these systems.

○ 15-16 WET-SUMP LUBRICATING SYSTEM Automobile engines and most small four-cycle engines use the "wet-sump" system. The "sump" is the oil pan or crankcase at the bottom of the engine. It is a "wet sump" because the engine oil is stored under the crankshaft as shown in Fig. 15-6. In many engines, an oil pump sends oil from the oil pan up through the engine oil lines to the moving engine parts. After lubricating, cleaning, and cooling these parts, the oil drops back down into the oil pan. The oil pump keeps the oil circulating continuously when the engine is operated. We will describe variations of this system later.

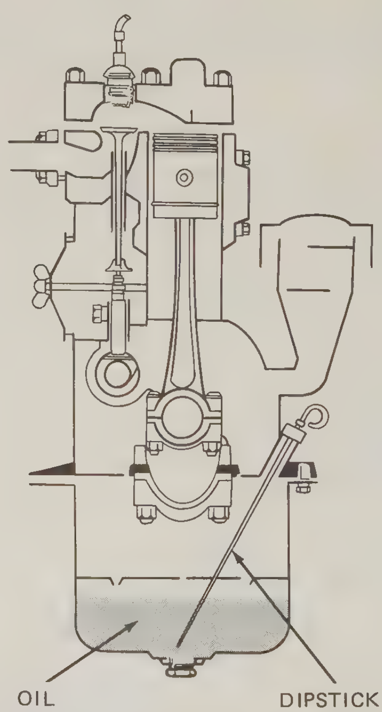


FIG. 15-6 Sectional view of a four-cycle engine, showing level of oil in oil pan and location of dipstick.

○ 15-17 DRY-SUMP LUBRICATING SYSTEM

The wet-sump lubricating system is not satisfactory for engines that are moving over rough terrain and operating at various angles from the vertical. The oil would, under these conditions, be splashing up all over the lower part of the engine. When the engine was tilted at an angle, the oil would be over on one side of the sump. Under these circumstances, the oil-pump intake would often be above the oil level in the sump. The oil pump would not be taking in any oil. It would not be sending oil to the upper part of the engine. As a result, the engine would soon fail.

To prevent this problem, a dry-sump system is used on engines that run over rough ground and are often tilted at sharp angles to the vertical. Some four-cycle motorcycle engines are equipped with dry-sump lubricating systems.

The dry-sump system works like this: It uses a double pump. As oil drops down from the engine into the oil pan or crankcase, one of the pumps removes the oil and sends it to an oil tank. From there, the second pump sends the oil to the moving engine parts. With this system, the second oil pump always has a tank full of oil to work from. There is no danger that the oil level will fall below the oil-pump intake. Therefore, all moving engine parts are properly lubricated at all times, regardless of the engine movement or tilt.

○ 15-18 SMALL-FOUR-CYCLE-ENGINE LUBRICATING SYSTEM

Small four-cycle engines use several different methods of getting oil to the moving parts in the engine. On engines that are either stationary or are moving over fairly level terrain, the wet-sump system is used. The simplest means of lubrication is to splash the oil about so that all parts are drenched, as shown in Fig. 15-7. The splashing is produced by a dipper on the lower end of the connecting rod such as those shown in Fig. 15-8. The oil in the crankcase is splashed every time the dipper reaches into it on the down stroke of the piston. Splash may also be accomplished by the use of an oil slinger which is rotated by the camshaft gear, as shown in Fig. 15-9.

A cam-operated barrel-type (also called a plunger-type) pump is used in some small engines to provide a pressure lubricating system. Three typical examples are shown in Figs. 15-10 to 15-12. A small gear-type pump operated by the camshaft gear is sometimes used on small vertical-shaft engines, as shown in Fig. 15-13.

Figure 15-14 shows the lubricating system used on a small multicylinder air-cooled engine. This engine uses spray nozzles to direct the oil to the moving parts.

Some vertical crankshaft four-cycle engines are lubricated by a pressure system that uses pulsating crankcase pressures as an oil pump. Figure 11-3 shows in cutaway view an engine with this type of lubricating system. The crankcase is sealed, similar

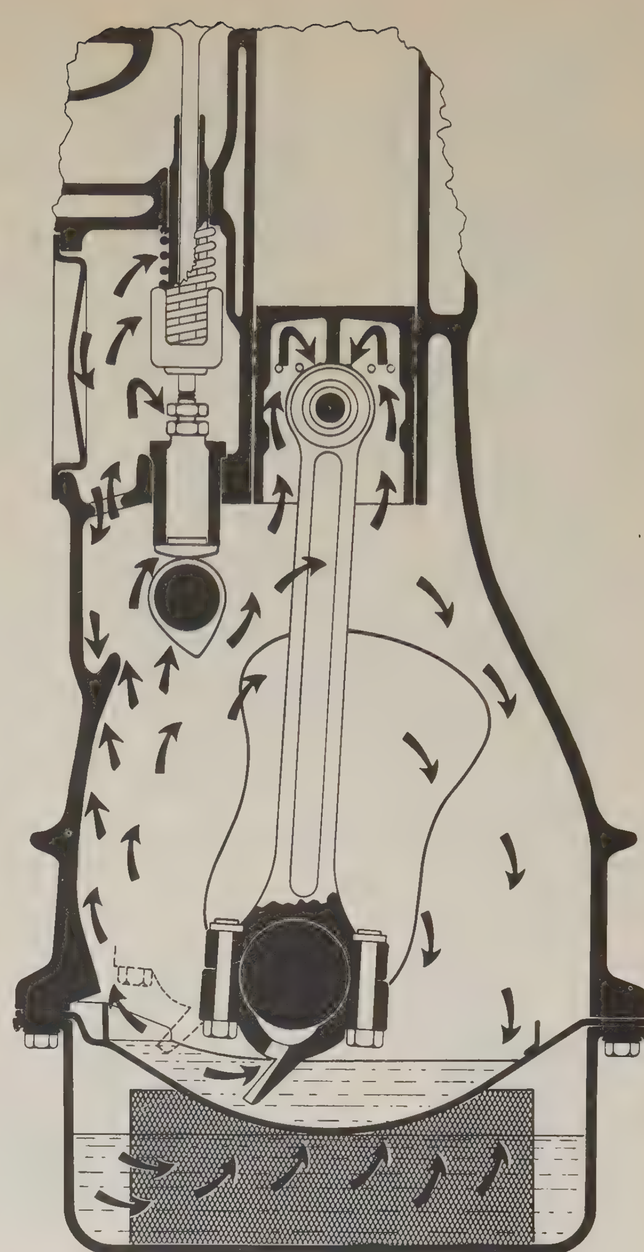


FIG. 15-7 Splash lubricating system on an L-head engine. The dipper on the connecting rod splashes oil, as shown by the arrows, every time the piston passes through BDC.

to the way that the crankcase for a two-cycle engine is sealed.

When the piston is at BDC, pressure in the crankcase is highest. In this position, the bottom port in the camshaft aligns with the oil pickup passage in the crankcase. The pressure above the oil forces it to fill the hollow camshaft. As the camshaft continues turning, the bottom port is closed off, trapping the oil under pressure in the hollow camshaft. Then the top port in the camshaft aligns with the main gallery in the crankcase. As this occurs, the piston has reached TDC, and pressure in the crankcase is lowest.

The combined effect of the oil trapped under pressure in the hollow camshaft and of the lower pressure in the crankcase causes some oil to flow out of the

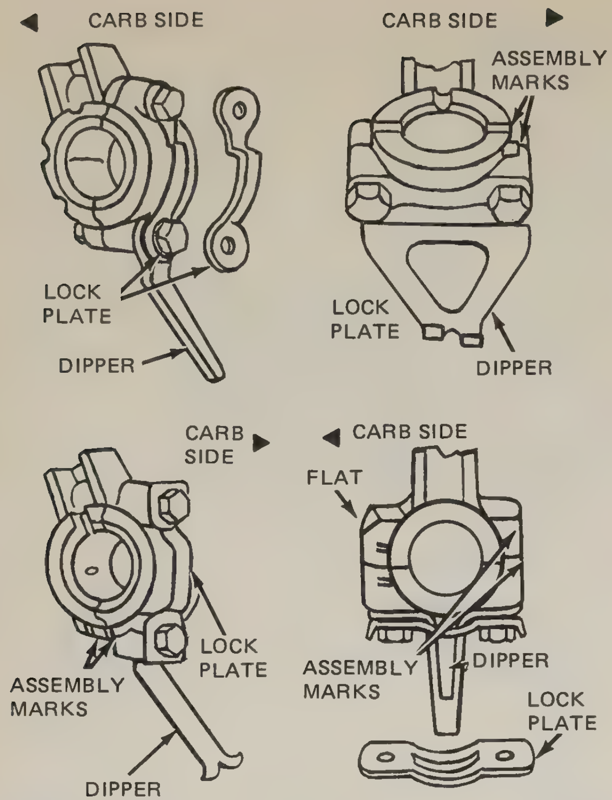


FIG. 15-8 Different ways in which the dipper is mounted on the connecting-rod cap.

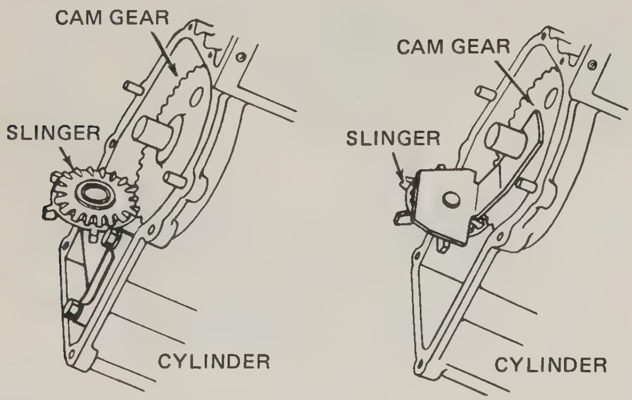


FIG. 15-9 Oil slinger is rotated by the camshaft gear.

camshaft. The oil flows through the main gallery to lubricate the top main bearing and then flows down to fill the oil cup. From the oil cup, oil flows into the hollow crankpin and from there through another hole to the connecting-rod bearing.

One advantage to this type of lubricating system is that it permits the engine to be operated at an angle. The maximum angle possible changes with oil level and position of the carburetor side of the engine (up or down). Various types of these engines can operate without harm at angles of 30 to 45°.

○ 15-19 OIL FILTERS In many four-cycle engines, the oil from the oil pump must first pass through an oil filter before it goes up to the engine. The oil filter

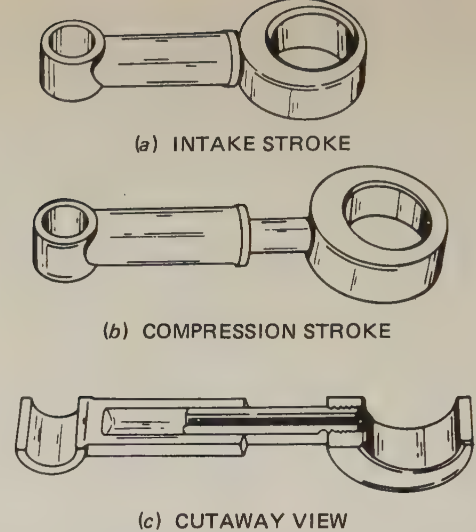


FIG. 15-10 Barrel-type lubricating pump used on the Lauson vertical-shaft engine.

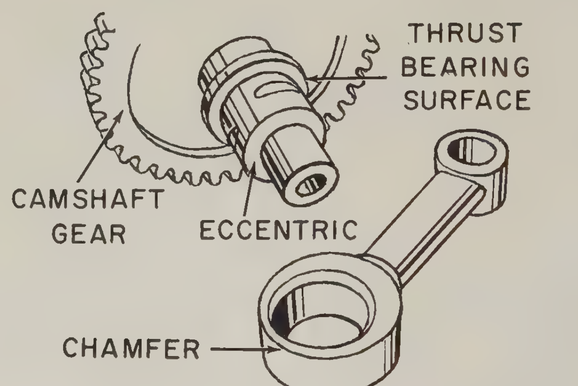


FIG. 15-11 The plunger-type oil pump is assembled on an eccentric on the camshaft. *(Tecumseh Products Company)*

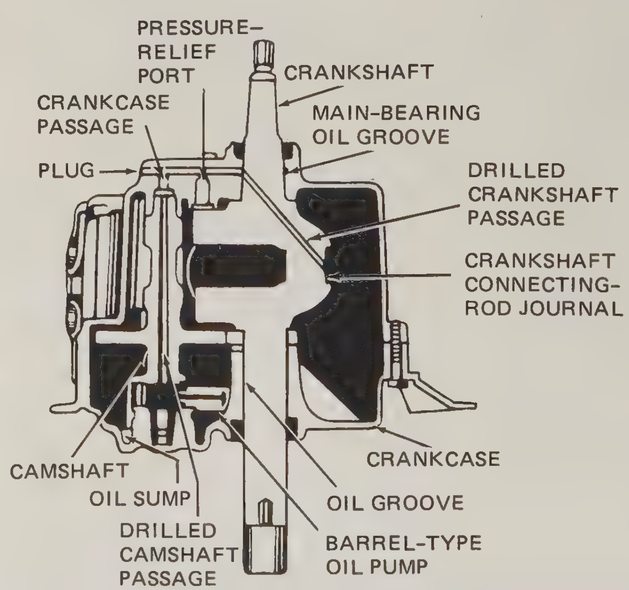


FIG. 15-12 Location of the barrel-type lubricating pump and the oil passages in the engine. *(Tecumseh Products Company)*

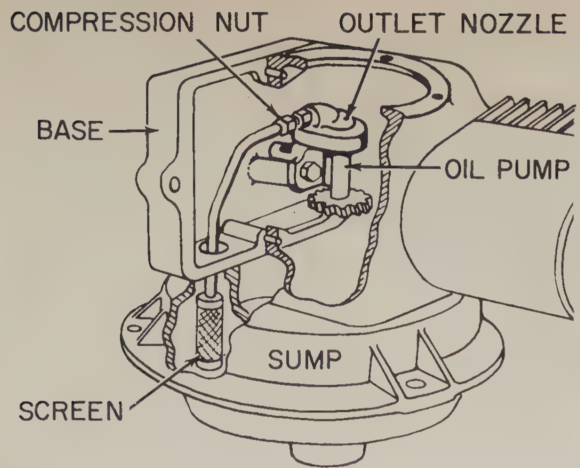


FIG. 15-13 Gear-driven oil pump. *(Briggs & Stratton Corporation)*

is the engine's main protection against dirt. The filter removes particles of carbon and dirt so they do not get into the engine and damage engine bearings and other parts. The filter contains a filtering element made of pleated paper or fibrous material. The oil passes through the filter, and the paper or fibers trap the dirt particles.

Figure 15-15 shows an oil filter. The filter element is housed in a replaceable can that is thrown away when the element becomes clogged with dirt. In the engine, the filter has a bypass relief valve, which consists of a spring-loaded ball. If the filter element becomes so clogged that all the oil needed by the engine cannot pass through the filter, the increased pressure from the oil causes the valve to open. This allows oil from the pump to bypass the filter and go directly to the engine. Figure 15-16 shows an oil filter that has a replaceable element.

○ 15-20 OIL LEVEL INDICATORS A dipstick is used to check the level of the oil in the crankcase (Fig. 15-17). To use the dipstick, pull it out, wipe it off, and put it back in place. Then pull it out again so that you can check the level of the oil shown on the dipstick.

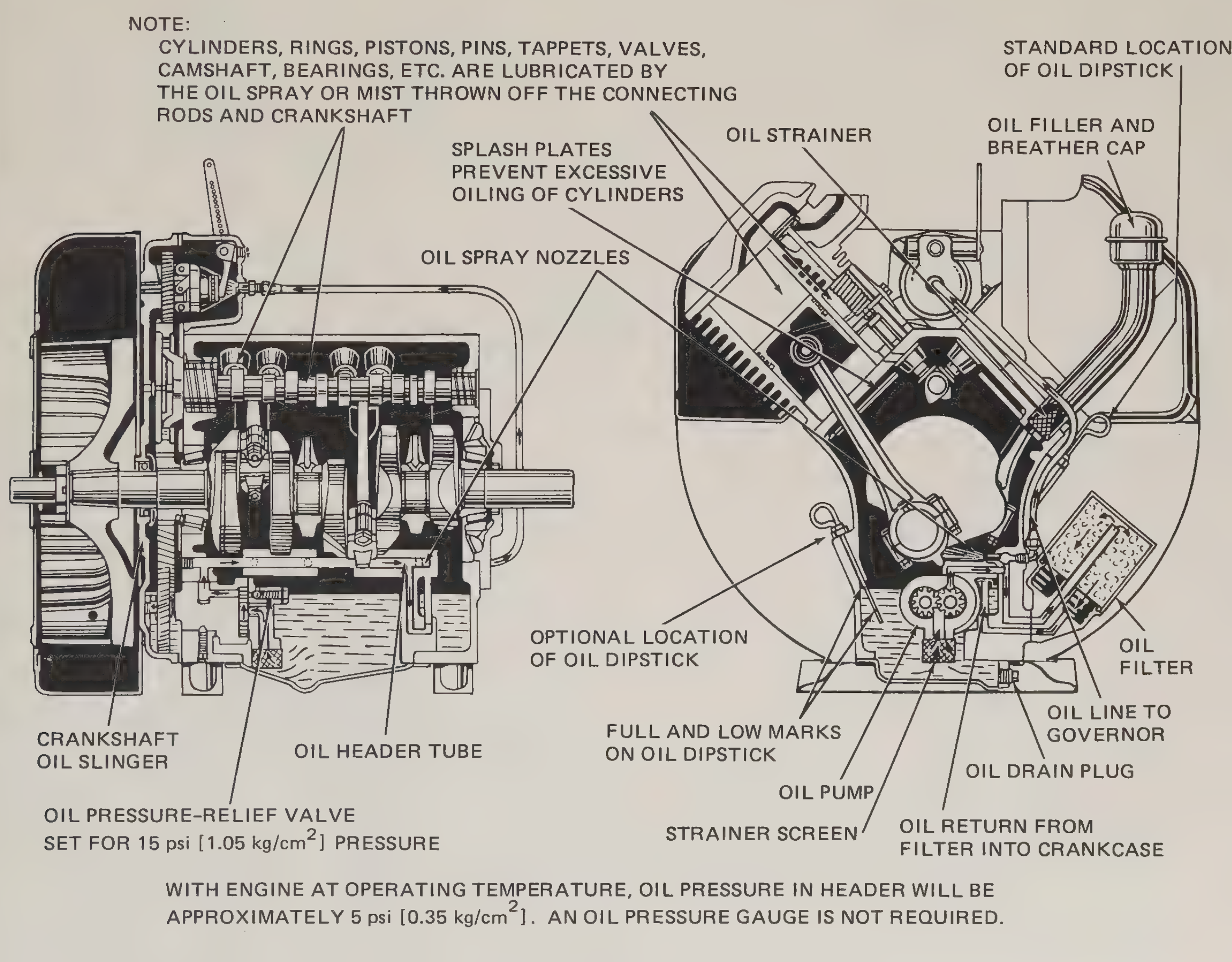
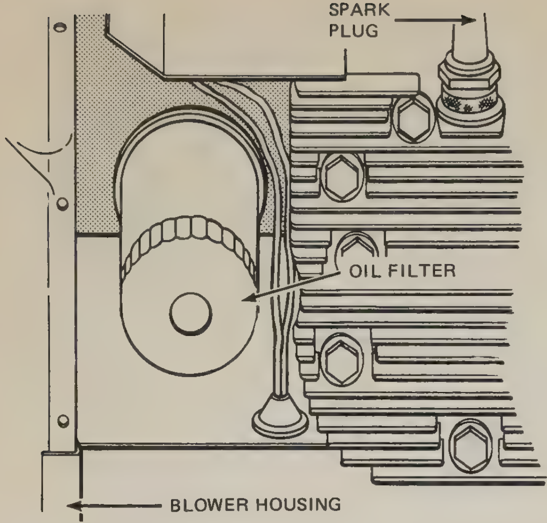


FIG. 15-14 Multiple-cylinder air-cooled engine lubricating system. *(Wisconsin Motor Corporation)*



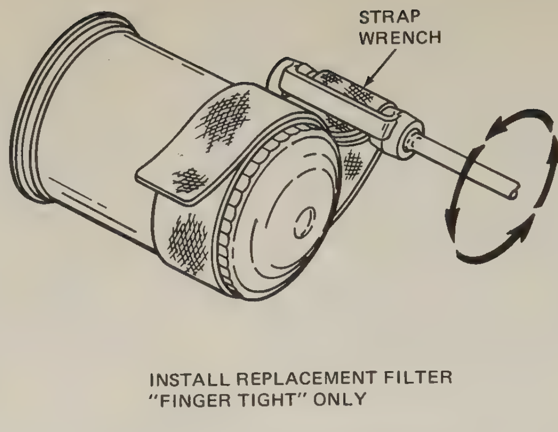
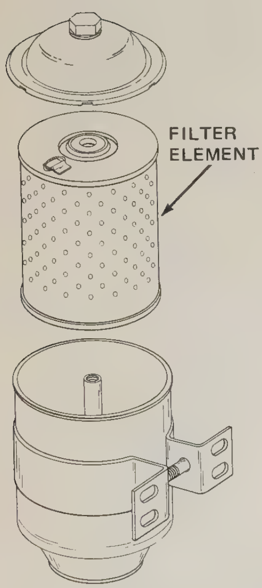


FIG. 15-15 Replaceable can type of oil filter. *(Kohler Company)*



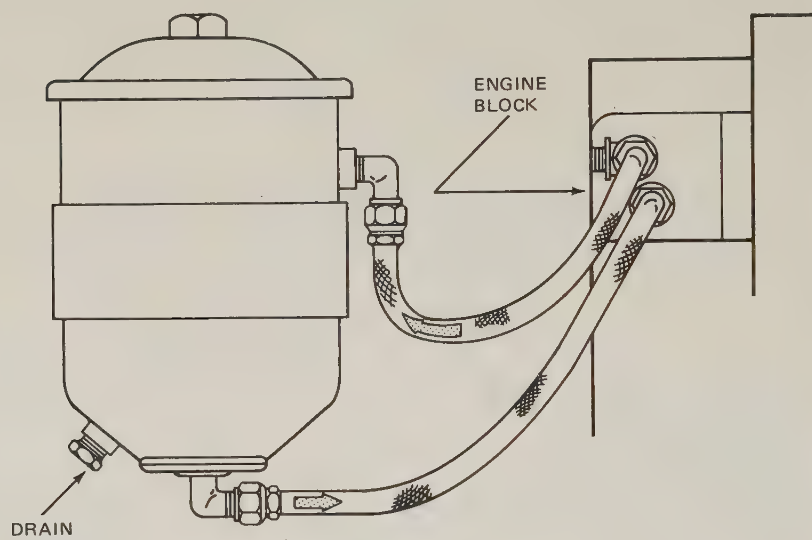


FIG. 15-16 An oil filter using a replaceable filter element. *(Kohler Company)*

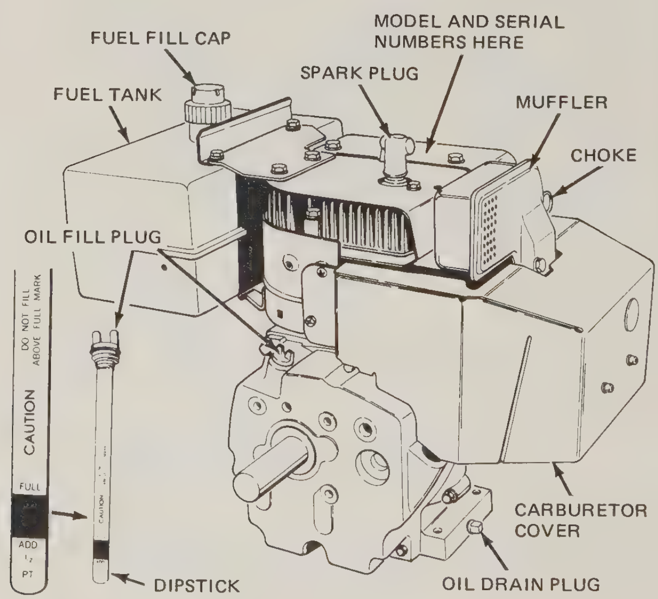


FIG. 15-17 Oil-fill plug and dipstick for a four-cycle engine. *(Tecumseh Products Company)*

REVIEW QUESTIONS

1. Name the six jobs that engine oil must do.
2. Explain how engine oil removes heat from the engine.
3. What is viscosity?
4. Does temperature influence oil viscosity? In what way?
5. Explain how sludge forms in the crankcase.
6. What are the five service ratings for gasoline-engine lubricating oils?
7. Is there any difference between the viscosity rating and the service rating of lubricating oil?
8. What two main engine factors influence oil consumption?
9. Explain why wear of engine parts increases oil consumption.
10. What are the two general types of four-cycle-engine lubricating systems?
11. Explain how the two-cycle engine is lubricated.
12. What is the purpose of the oil filter?

SELF PROJECT

Cans of engine oil have information on the properties of and additives in the oil. Whenever you have a chance, copy this information on sheets of paper to file in your notebook. Check the cans containing oil of different viscosity numbers and service ratings. Build up as complete a file as you can. After you have compiled a file on one brand of oil (Gulf, for example), work on getting a file for other brands (Texaco, Shell, and so on).

16 Chapter

Gasoline

After studying this chapter, you should be able to:

1. **Describe the composition of gasoline and the additives that go into it**
2. **Explain what volatility is and how it affects engine operation**
3. **Discuss engine detonation and what is done to prevent it**
4. **Explain why lead has been removed from some gasolines**
5. **Explain the relationship between compression ratio and detonation**

○ 16-1 WHAT GASOLINE IS Gasoline is often referred to as "gas," which is slang for the common liquid fuel gasoline. The sort of gas you burn in a gas stove or use to heat a house is usually a gas that is delivered through gas lines or pipes. There is a gas that is a gas (a vapor), and there is a "gas" that is gasoline (a liquid).

Gasoline is a hydrocarbon (HC) made up largely of hydrogen and carbon compounds. These two elements unite readily with oxygen, a common element which makes up about 20 percent of our air. When hydrogen unites with oxygen, water (H_2O) is formed. When carbon unites with oxygen, carbon monoxide (CO) and carbon dioxide (CO_2) are formed. If all the gasoline burned completely in the engine, all that would come out would be water (H_2O) and carbon dioxide (CO_2). However, perfect combustion is not achieved in the engine. So some CO and HC are present in the exhaust gases. These two compounds, plus a third compound, nitrogen oxides (NO_x), are the major pollutants emitted by internal-combustion engines.

The combustion of gasoline in the engine cylinder produces heat and the high pressure that forces the piston down. This is how the engine produces power.

○ 16-2 ORIGIN OF GASOLINE Gasoline, diesel fuel oil, liquefied petroleum gas (LPG), and many other compounds are obtained from petroleum, or crude oil. No one knows exactly how petroleum originated. It is found in "pools" under the ground. There is evidence that it was formed over a period of many millions of years from animal or vegetable sources. The petroleum usually is under considerable pressure. When a well is drilled down to a pool or reservoir, the petroleum gushes up out of the earth. However, in many wells, the natural pressure is not great enough to force the crude oil out. With these wells, pressure is applied from above the ground by artificial means to force the crude oil out.

Petroleum is a very intricate mixture of many compounds. The oil refinery separates the petroleum into various substances. It alters many of the original compounds and forms new compounds in the refining process. From the refinery come many types and grades of lubricating oil, fuel oil of various types for diesel engines and heating, gasoline of many grades and types, kerosene, LPG, and so on.

Gasoline is blended from a number of different basic hydrocarbons, each with its own set of characteristics. By blending various basic fuels, a gasoline is obtained that provides satisfactory engine operation under the many different operating conditions that the engine may meet. Factors that must be considered in blending gasoline include volatility, antiknock value, and freedom from harmful chemicals and gum. These factors are discussed in detail in following sections.

○ 16-3 VOLATILITY Volatility refers to the ease with which gasoline and other liquids vaporize. The volatility of a simple compound like water or alcohol is determined by increasing its temperature until it boils, or vaporizes. A liquid that vaporizes at a relatively low temperature has a high volatility. If its boiling point is high, it has a low volatility. A certain heavy oil, for example, has a low volatility. It does not boil until it reaches a temperature of over 600°F [316°C]. Water is relatively volatile. It boils at 212°F [100°C]. Gasoline is still more volatile.

A highly volatile substance evaporates much faster at a low temperature than a substance with a low volatility. At room temperature, alcohol and gasoline evaporate more rapidly than water.

Gasoline is blended from different hydrocarbon compounds that have different volatilities, or boiling points. Some compounds of gasoline therefore evaporate more readily at low temperatures than others. This combination assures satisfactory operation under the various operating conditions that the engine meets.

○ 16-4 GASOLINE ANTIKNOCK CHARACTERISTICS During normal combustion in the engine cylinder, an even increase of pressure occurs. But if the fuel burns too rapidly, or "explodes," there is a sudden and sharp pressure increase. This detonation, or spark knock, may produce a rapping or pinging noise that sounds almost as though the piston head had been struck a hard hammer blow. Actually, the sudden pressure increase does impose a sudden heavy load on the piston that is almost like a hammer blow. This can damage the engine, wear moving parts rapidly, and even cause parts to break. Furthermore, some of the energy in the gasoline is wasted. The sudden pressure increase does not contribute much to the production of power.

○ 16-5 COMPRESSION RATIO Before we discuss the antiknock value of gasoline further, let us review the engine compression ratio. We discussed compression ratio in an earlier chapter (○ 14-13). Now let us relate it to engine detonation.

The higher the compression ratio, the more the air-fuel mixture is "squeezed" on the compression stroke. There is a higher initial pressure at the beginning of the power stroke. This means, in turn, that there is more pressure on the piston as combustion begins. This fact brings us to the basic advantage of higher compression ratios. With more pressure on the piston during the combustion stroke, more power results. Therefore, increasing the compression ratio increases engine output. That is the reason why engine designers and manufacturers are producing engines of higher and higher compression ratios. By redesigning the engine to step up the compression ratio, they get an engine with a higher horsepower output without a comparable increase in size. In fact, modern high-compression engines weigh much less and are much more powerful than older engines.

The increase of compression ratio has brought about certain difficulties. A high-compression engine has a greater tendency to detonate. It has been necessary to find fuels that resist detonation for these high-compression engines. A great deal of research, both in the laboratory and in testing facilities, has been done to find these antiknock fuels.

To understand why detonation occurs, it is first necessary to understand what happens to any gas when it is compressed. When air is compressed to one-fifteenth of its original volume, or the compression ratio is 15 : 1, the air temperature increases to about 1000°F [537.8°C]. The more a gas is compressed, the higher its temperature rises. This temperature rise is called heat of compression.

○ 16-6 CAUSE OF DETONATION During normal burning of fuel in the combustion chamber, the spark at the spark plug starts the burning process. A wall of flame spreads out in all directions from the spark, almost like a rubber balloon being blown up. The wall of flame travels rapidly outward through the compressed mixture in the combustion chamber until all the charge is burned, as shown in Fig. 16-1. The speed with which the flame travels is called the rate of flame propagation. The movement of the flame wall through the combustion chamber during normal combustion is shown in the top row of pictures in Fig. 16-2. During combustion, the pressure increases to several hundred psi. It may exceed 1000 psi [70.3 kg/cm^3] in high-compression engines.

Under certain conditions, the last part of the compressed air-fuel mixture will explode before the flame front reaches it, as shown at the bottom in Fig. 16-2. The unburned mixture, called end gas, is being subjected to increasing pressure as the flame progresses

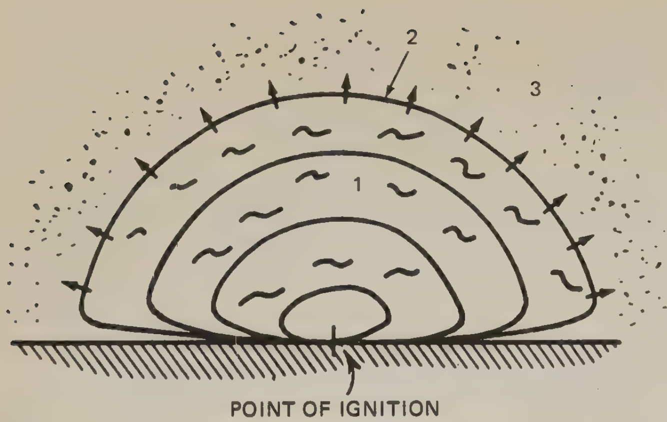


FIG. 16-1 Normal flame travel in the combustion chamber. (1) Flame kernel consisting of combustion products; (2) flame front area; (3) unburned mixture. *(General Motors Corporation)*

FIG. 16-3 The appearance of a piston that has failed due to detonation. Note how the ring lands have been shattered and chipped away by the high-pressure shock wave. *(TRW, Inc.)*

through the air-fuel mixture. This increases the temperature of the end gas owing to heat of compression and also to radiated heat from the combustion process. If the temperature reaches the critical point, the end gas will explode before the flame front arrives. The effect is almost the same as if the pistonhead had been struck a heavy hammer blow. In fact, it sounds as though this had happened. The sudden shock load due to detonation of the last part of the charge increases wear on bearings and other engine parts, and it may actually break engine parts if the shock is severe enough. Figure 16-3 shows a piston that has been damaged by detonation.

○ 16-7 COMPRESSION RATIO VERSUS DETONATION As compression ratios of engines have gone up, so has the tendency of the engines to detonate. The reason is that with higher compression ratios, the mixture, at TDC, is more highly compressed and is at a higher initial temperature. With higher initial pressure and temperature, the temperature at which detonation occurs is reached sooner. Therefore, high-compression engines have a greater tendency to detonate. However, special fuels have been developed for use in such engines. These special fuels have a greater resistance to being set off by heat of compression. They are less apt to explode suddenly. The right fuel for an engine will depend for ignition upon the wall of flame traveling through the air-fuel mixture.

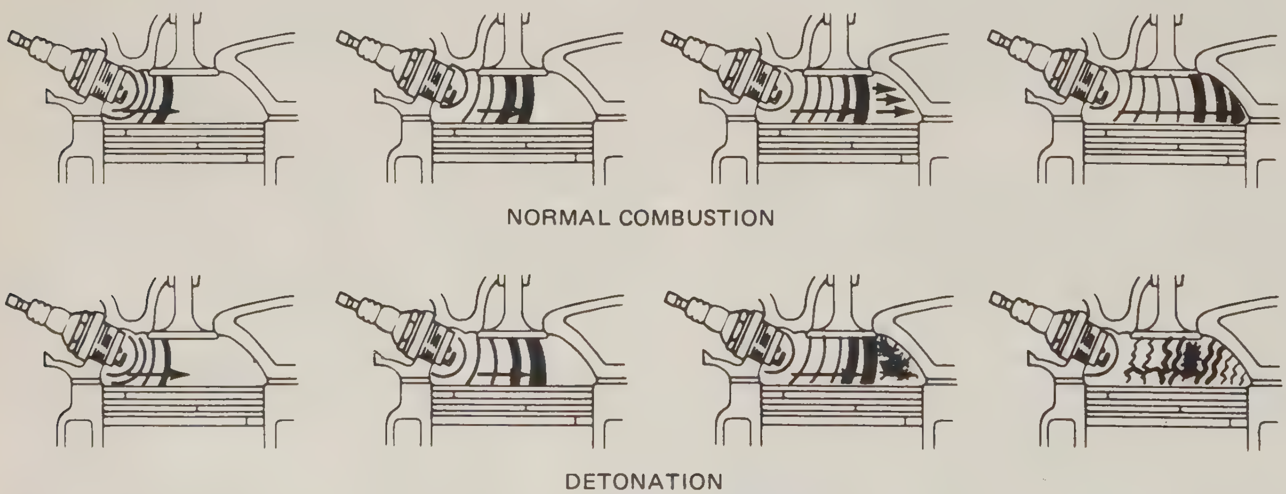


FIG. 16-2 Normal combustion without detonation is shown in the top row. The fuel charge burns smoothly from beginning to end, providing an even, powerful thrust to the piston. Detonation is shown in the bottom row. The last part of the fuel also explodes, or burns, instantaneously, producing detonation or spark knock. *(General Motors Corporation)*

○ 16-8 CONTROLLING ANTIKNOCK VALUES

There are several methods of testing fuels to determine their tendency to detonate in engines. Some fuels detonate rather easily. Others have a high resistance to detonation, or a high antiknock rating. The actual rating of a fuel for its antiknock value is made in terms of octane number, referred to as ON. A high-octane gasoline is highly resistant to detonation, while a low-octane gasoline detonates rather easily. There is a fuel called iso-octane that is extremely resistant to detonation. It is given an octane rating, or ON, of 100. Another fuel, called heptane, detonates very easily. It is given an ON of zero. A mixture of half iso-octane and half heptane, by volume, would have a 50 ON. A mixture of 90 percent iso-octane and 10 percent heptane would have an ON of 90.

Actually, iso-octane and heptane are reference fuels, used only to rate unknown fuels. One rating procedure makes use of a test engine built so that its compression ratio can be varied. A fuel to be rated is used to run the engine. The compression ratio is increased until a certain intensity of detonation is obtained. Then, reference fuels of varying proportions of iso-octane and heptane are used to run the engine. The octane rating of the reference fuel is decreased, by using smaller percentages of iso-octane, until the same intensity of detonation results as obtained with the fuel to be rated. The fuel being rated is then given the same octane number as the reference fuel, since both produce the same amount of detonation. If the reference fuel has 88 percent iso-octane, for example, then it and the fuel being tested are considered to have the same 88 ON.

Actually, there are two testing procedures using the variable-compression-ratio engine. One method is called the research method. It is performed at comparatively low speed and air-inlet temperatures. The octane number of a gasoline tested by this method is called the research octane number, or RON. The other method is called the motor method. It is performed at higher engine speed and air-inlet temperatures. The octane number of a gasoline tested by this method is called the motor octane number, or MON. Commercial gasoline typically will have an octane number as much as eight numbers lower by the motor method than by the research method.

The two numbers are averaged to get the advertised octane number of gasoline. This is the number that you find posted on gasoline pumps in service stations. For example, suppose a gasoline had an RON of 98 and an MON of 90. The posted ON would then be 94.

$$\frac{98 + 90}{2} = 94$$

The federal octane rating is actually the average of the research octane number (RON) and the motor octane number (MON). Generally, the federal octane numbers that you find posted on gasoline pumps are around 87 for unleaded regular gasoline, 90 for leaded regular gasoline, and 95 for leaded premiums.

○ 16-9 DETONATION VERSUS PREIGNITION

Let us define these two terms. *Detonation* is a secondary explosion that occurs after the spark at the spark-plug gap. *Preignition* is ignition of the air-fuel mixture prior to the occurrence of the spark at the spark-plug gap. Figure 16-4 shows a piston that has been damaged by preignition.

We have discussed the type of spark knock that results from detonation, or sudden explosion, of the last part of the fuel charge in the cylinder. This type of noise is usually regular in character. It is most noticeable when the engine is accelerated or is under heavy load, as when climbing a hill. Under these conditions, the throttle is fully open, or nearly so. The engine is taking in a full air-fuel charge on every intake stroke. Volumetric efficiency is high. This means that high compression pressures may be reached after the mixture is ignited.

Preignition, surface ignition, and rumble are usually considered to be service problems. They result from inadequate servicing of the engine, such as the installation of the wrong spark plugs which run too hot and the use of incorrect fuels and lubricating oils for the engine and the type of operation. With incorrect fuel or oil, engine deposits may occur which will lead to surface ignition and rumble. Engine deposits can also increase the compression ratio so that the engine becomes more likely to detonate.

○ 16-10 CHEMICAL CONTROL OF DETONATION

Certain chemicals added to gasoline tend to prevent detonation of the last part of the fuel charge, the end

FIG. 16-4 The appearance of a piston that has failed due to preignition. The excessive temperature has melted a hole through the pistonhead. *(TRW, Inc.)*

gas, during combustion. One theory is that the chemicals increase the reaction time of the fuel. In other words, they increase the time that the air-fuel mixture remains stable. This increased time gives the flame front time to reach the end gas before it explodes. The result is that it enters into the normal combustion process. One of the compounds most successful in preventing detonation is tetraethyl lead, commonly called ethyl or tel. A small amount added to gasoline raises the octane number of the gasoline.

○ 16-11 OTHER FACTORS AFFECTING DETONATION

The shape of the combustion chamber, in addition to the compression ratio, has a great effect on the tendency of the engine to detonate. The combustion chamber of an I-head engine is bounded at the top by the cylinder head, intake and exhaust valves, and the spark plug. It is bounded at the bottom by the pistonhead and top compression ring as shown in Fig. 16-5. There are two general shapes—wedge and hemispheric—as shown in Fig. 16-6. The shape determines turbulence, squish, and quench. These three factors affect detonation.

○ 16-12 TURBULENCE

When you stir your coffee, you impart turbulence to it so that the cream and sugar mix with the coffee. In a like manner, imparting turbulence to the air-fuel mixture entering the combustion chamber assures more uniform mixing so that the combustion will be more uniform. Turbulence also reduces the time required for the flame front to sweep through the compressed mixture.

○ 16-13 SQUISH

Squish refers to the way in which the piston, in some combustion chambers, squishes, or squeezes, a part of the air-fuel mixture at the end of the compression stroke. Figure 16-6 shows the squish area in a combustion chamber. As the piston nears TDC, the mixture is squished, or pushed, out of the squish area. As it squirts out, it promotes turbulence and further mixing of the air-fuel mixture.

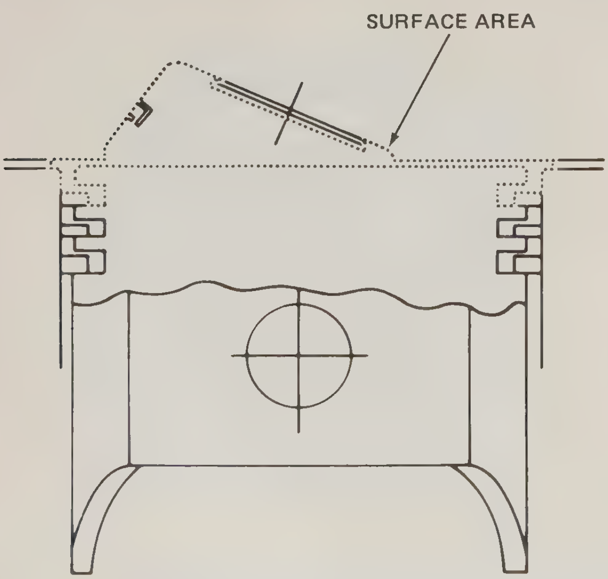


FIG. 16-5 Combustion surface area in the combustion chamber. The surface area is indicated by the dotted line.

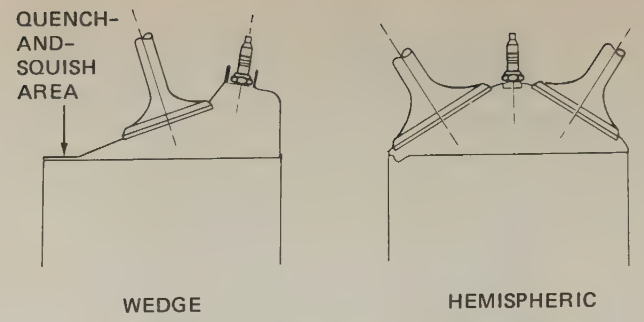


FIG. 16-6 Wedge and hemispheric combustion chambers. *(General Motors Corporation)*

○ 16-14 QUENCH

Detonation results when the end-gas temperature goes too high and the end gas explodes before the flame front reaches it. However, if some heat is extracted from the end gas, then its temperature will not reach the detonation point. In the arrangement shown in the left part of Fig. 16-6, the squish area is also a quench area. The closeness of the cylinder head to the piston and the relative coolness of these metal surfaces cause heat to be extracted from the end gas. Therefore, the tendency for detonation to occur is quenched.

○ 16-15 HEMISPHERIC COMBUSTION CHAMBER

With the hemispheric combustion chamber, the spark plug can be located near the center of the dome. Then, when combustion starts, the flame front has a relatively short distance to travel. There are no distant pockets of end gas to detonate. The chamber has no squish or quench areas. However, there is relatively little turbulence.

○ 16-16 WEDGE COMBUSTION CHAMBER

With the wedge combustion chamber, the spark plug is located to one side. The flame front must travel a greater distance to reach the end of the wedge. The end of the wedge has a squish-and-quench area which cools the end gas. This prevents detonation and at the same time imparts turbulence to the mixture.

○ 16-17 SMOG

The shape of the combustion chamber also influences the number of pollutants in the exhaust gases. The relatively cool metal surfaces of the cylinder head and piston top retard combustion. Therefore, the layers of air-fuel mixture next to these metal surfaces will not burn completely. The wedge combustion chamber, with its larger surface area, produces more pollutants per power stroke than the hemispheric combustion chamber.

○ 16-18 OPERATING FACTORS AFFECTING DETONATION

In any engine many operating factors affect the tendency to detonate. Many tests have been made to establish the relationship between temperature, humidity, ignition spark advance, engine deposits, and detonation tendency. Test results are usually given in terms of the octane-number increase necessary to eliminate detonation.

For example, a hot engine detonates more easily than a cold engine. To get exact data on this, an engine is operated cold on the lowest-octane fuel it can use without detonating. The difference between the octane numbers is an indication of the increased octane requirements as the engine warms up. For example, one test showed that increasing the temperature of the coolant in a liquid-cooled engine from 100 to 190°F [37.8 to 87.8°C] increased the octane requirements by 22 numbers, from 70 to 92 in this engine. Therefore, as an air-cooled engine gets hot, its octane requirements go up.

○ 16-19 CHEMICAL VERSUS MECHANICAL OCTANE

Octane numbers can be increased by adding a chemical such as tel (tetraethyl lead). Octane requirements of the engine can be changed by changes in engine design and by changes in operating conditions. The previous sections discussed several operating conditions that increase or lower octane requirements. Increasing compression ratio increases octane needs. Mechanical octane, or octane need, of an engine can also be altered by changes in piston and combustion-chamber shape.

Figure 16-7 shows a series of combustion-chamber shapes which were tested during design work on an engine. All these were run under identical conditions of speed, power output, compression ratio, and so forth. The only variation was in the octane number of the fuels used. Fuels were selected for each design as required to avoid detonation. It was found that design A required 96-octane fuel to run without detonating, whereas design J required only 88-octane fuel. There is a difference of 8 mechanical octanes between design A and design J.

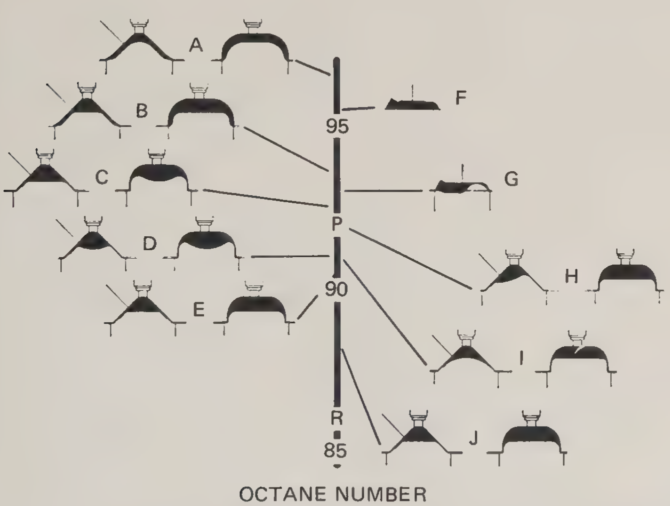


FIG. 16-7 Octane tree showing the relationship between combustion-chamber design and octane requirements. Two views (end and side) of the combustion chamber are shown for each design except for designs *F* and *G*. *(Buick Motor Division of General Motors Corporation)*

○ 16-20 GASOLINE ADDITIVES

In addition to the antiknock compounds and their related lead-compound-vaporizing substances which are put into gasoline to raise its octane rating, many other additives are used. Major additives include the following:

1. Oxidation inhibitors to help prevent the formation of gum while the gasoline is in storage.
2. Metal deactivators to protect the gasoline from the harmful effects of certain metals picked up in the refining process or in the engine fuel system.
3. Antirust agents to protect the engine fuel system.
4. Anti-icers to combat carburetor icing and fuel-line freeze.
5. Detergents to keep the carburetor clean.
6. Dye for identification.

○ 16-21 GASOLINE FOR SMALL ENGINES

In the past, many small-engine manufacturers recommended the use of a gasoline with at least a 90 RON. Today, in these engines, a gasoline with a pump sticker rating of 85 octane or higher may be used.

Some manufacturers of four-cycle small engines now allow the use of unleaded gasoline in their engines. However, the unleaded gasoline must have a pump sticker octane rating of 85 or higher, or a research octane rating of 90 or higher. In addition to causing less air pollution from the exhaust gas, the unleaded fuel greatly reduces deposits on the spark plugs and in the combustion chamber.

Always use the gasoline specified by the engine manufacturer for use in the engine. Failure to do so may cause premature rapid wear of the engine parts. For example, engines designed to use unleaded gasoline may have coated valves and hardened valve seats. An older engine, without these features built in, may have rapid wear of the valves and valve seats if it is operated on unleaded gasoline.

REVIEW QUESTIONS

1. With perfect combustion, what two compounds would be formed when gasoline burns?
2. Name three pollutants emitted from engines.
3. What is volatility? Why is it important in gasoline?

4. What does the term "antiknock value" mean?
5. What is heat of compression?
6. Explain the cause of detonation produced by heat of compression.
7. What effect does increasing the compression ratio have on detonation? Why?
8. Describe one method of measuring the antiknock value of a gasoline.
9. What does octane number mean?
10. What is the difference between detonation and preignition?
11. What effect does lead have on valves and valve seats?
12. Why has lead been removed from gasoline?
13. What is quench?
14. What is squish?
15. What are the two basic combustion-chamber shapes?
16. Name six gasoline additives.

SELF PROJECT

Find out how gasoline is made. Go to your local library and look in an encyclopedia for information on oil and gasoline. Make notes on how engineers prospect (look for) oil in the earth. Prospectors drill many wells into the earth in their search for oil. Most of these are dry wells. They contain no oil. But when prospectors do find oil, a whole series of events sets in. The oil must be controlled as it comes from the well. It must be transported to refineries. The refineries put the crude oil through a series of processes. Out of the refining processes come many different products ranging from grease and other lubricants to fuel oil and gasoline.

17
Chapter

Fuel Systems for Small Engines

After studying this chapter, you should be able to:

1. **List the types of fuel systems used on small engines**
2. **List the parts of the fuel system and the purpose and operation of each**
3. **Describe the construction of a basic carburetor**
4. **Explain why a governor is needed and how each type of governor operates**

○ 17-1 INTRODUCTION TO FUEL SYSTEMS

The air-fuel mixture must have the proper proportions of air and gasoline for good engine operation. If the mixture does not have enough gasoline vapor (mixture too lean) or if the mixture has too much gasoline vapor (mixture too rich), the engine will not run properly. Also, to start a cold engine, the mixture must be enriched. It must have a higher proportion of gasoline vapor in it.

In this chapter, we look at the various fuel systems used in small engines. A variety of fuel systems and carburetors are used in small engines, because small engines are used in so many different ways. Some small engines, such as those used in lawn mowers, are designed to run at one speed in an upright position. Other small engines, such as those used in chain saws, are designed to be used in many different positions.

○ 17-2 TYPICAL SMALL-ENGINE FUEL SYSTEMS

The fuel system for a small engine (Fig. 17-1) includes a fuel tank, fuel filter, carburetor, air cleaner, and (on some engines) a fuel pump. Three general types of fuel systems are used on small engines. These are as follows:

1. The gravity-feed fuel system
2. The suction-feed fuel system
3. The pressure-feed fuel system

The two most commonly used fuel systems on small engines are the gravity-feed system and the suction-feed system. These are shown in Fig. 17-2. Other small engines use a pressure-feed system, such as shown in Fig. 17-3. This type of fuel system requires the use of a fuel pump.

Now, let us take a look at the parts of a typical gravity-feed fuel system used on a two-cycle engine in a power lawn mower. This type of fuel system is

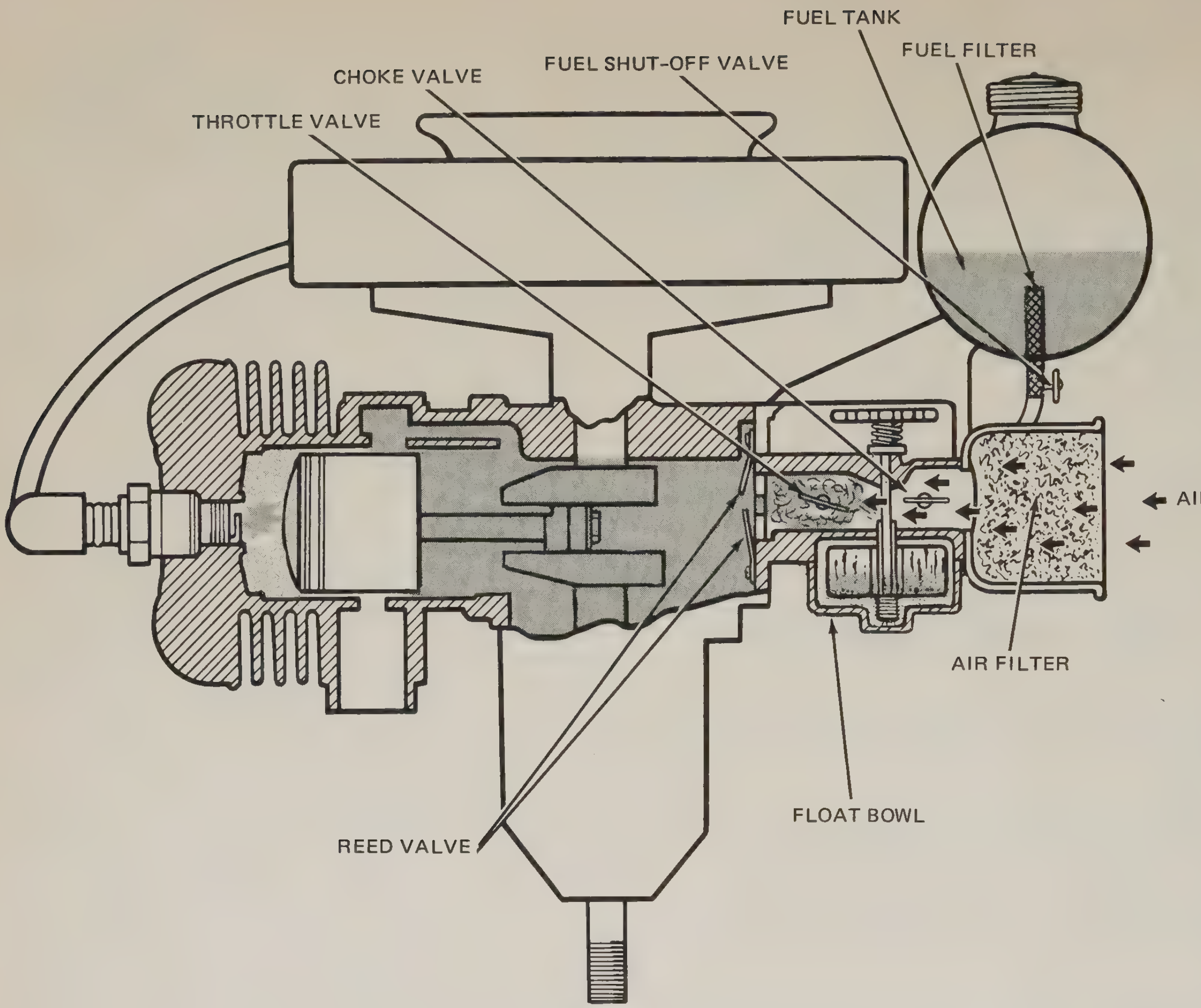


FIG. 17-1 Fuel system for two-cycle engine. *(Lawn Boy Division of Outboard Marine Corporation)*

shown in Figs. 17-1 and 17-2. A similar system is shown in Fig. 17-4. Later we will discuss the other types of fuel systems used on small engines. The engine with which this gravity-feed fuel system is used is described and illustrated in Chap. 9.

In a gravity-feed fuel system, gasoline flows down by gravity from the fuel tank through a fuel filter. From the filter, the gasoline flows through a fuel line to the carburetor. When the engine is running, air passes through the air cleaner on the way to the carburetor. In the carburetor, the air picks up a charge of gasoline. Then the air-fuel mixture enters the engine. This action already has been discussed in Chap. 9.

The carburetor itself is shown in Figs. 17-1, 17-2, and 17-4. Essential parts of a typical carburetor include the air cleaner, float bowl, choke valve, throttle valve, and (on some carburetors) the fuel nozzle with adjustment needle. In later sections of this chapter, the operation and construction of small-engine carburetors are discussed in detail.

○ 17-3 FUEL TANK The fuel tank shown in Fig. 17-4 is made of sheet metal or plastic. It has a filler cap which is removed to add gasoline. The filler cap has a small hole in it for air to enter the tank as gasoline is used. A fuel strainer, or fuel filter, at the tank outlet (Fig. 17-4) filters out any dirt that might have entered the tank. This prevents the dirt from entering the carburetor, where it could clog fuel passages and stop the engine.

○ 17-4 AIR CLEANER The engine shown in Fig. 17-1 uses a metal-mesh air cleaner. The mesh is packed into the filter case and moistened with oil. It traps particles of dirt that enter with the air. Over a period of time, the filter can become so loaded with dirt that it restricts the flow of air. This prevents normal operation of the engine. Before this happens, the filter should be removed and washed in clean solvent. Then the filter should be reoiled and reinstalled on the carburetor.

Various other types of air cleaner are shown in Fig. 17-5. In the widely used oiled-foam type, the lip of the foam must extend over the edge of the air-cleaner body when the cover is in place. There the lip forms a

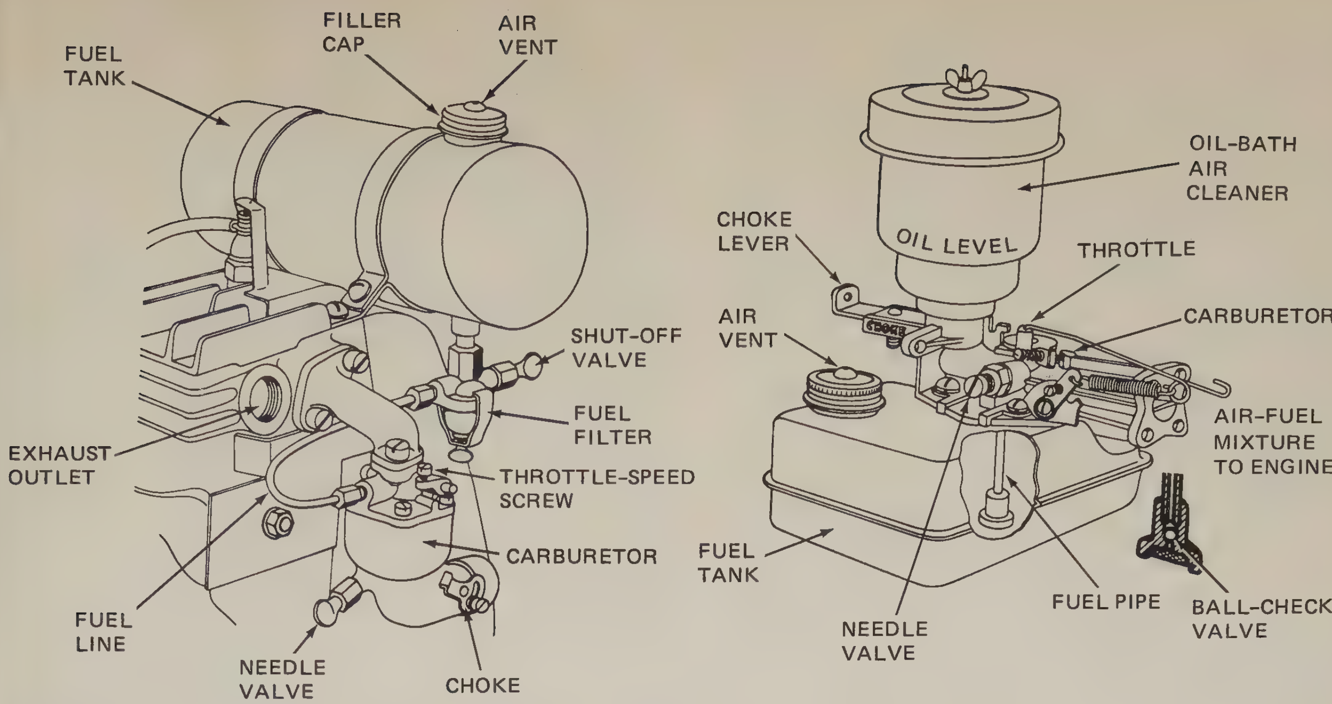


FIG. 17-2 Two types of small-engine fuel systems: (left) a gravity-feed system and (right) a suction-feed system. These fuel systems are used on single-cylinder four-cycle engines. *(Briggs & Stratton Corporation)*

seal around the outside of the air cleaner so no air can enter the carburetor without first passing through the oiled foam.

Some engines use an oil-bath air cleaner (Fig. 17-5). Others use a dry element. In the oil-bath air cleaner, there is a reservoir containing oil past which the incoming air must flow. As the air does this, it picks up particles of oil and carries them up into the filter mesh. This tends to wash off dirt particles, which drain back into the oil reservoir with the oil. On these filters, the oil must be changed whenever the wire mesh is washed.

○ 17-5 FUEL FILTER A fuel filter, or strainer, usually is installed on an engine. The filter is mounted at the outlet of the fuel tank, in the carburetor fuel inlet, or in the fuel line between the fuel tank and the carburetor. In Fig. 17-3, the fuel system shown has a fuel filter in the bottom of the fuel tank. In Fig. 17-4, a fuel filter is installed ahead of the fuel pump, in the fuel line from the fuel tank. Regardless of its position, the fuel filter has the job of filtering out any dirt particles or grit in the gasoline.

○ 17-6 FLOAT BOWL The purpose of the float system is to prevent the delivery of too much gasoline to the carburetor. Without the float system, all the fuel in the fuel tank would run down into the carburetor. The float system is made up of a small bowl, a float of metal or cork, and a needle valve that is operated by the float. Figure 17-6 is a simplified drawing of a float system. When gasoline from the fuel tank enters the float bowl, the float is raised. As the float moves upward, it lifts the needle valve into the inlet hole (called the *valve seat*).

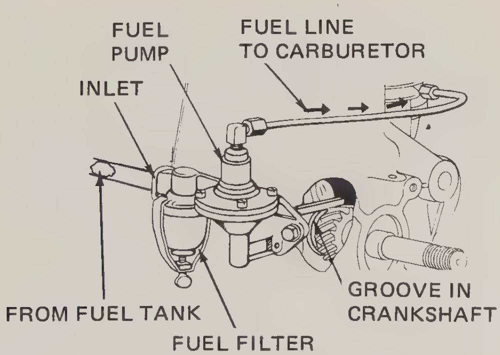


FIG. 17-3 Pressure-feed fuel system for a small engine. The engine has been partly cut away in the illustration so the position of the pump lever on the groove in the crankshaft eccentric can be seen.

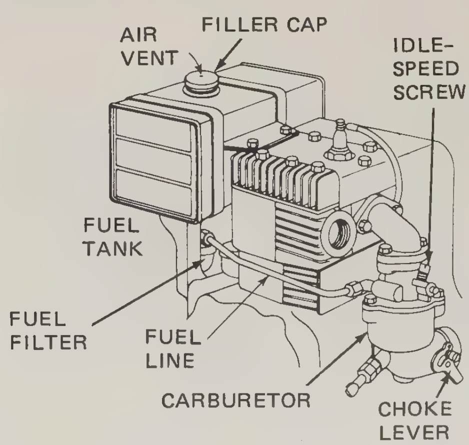
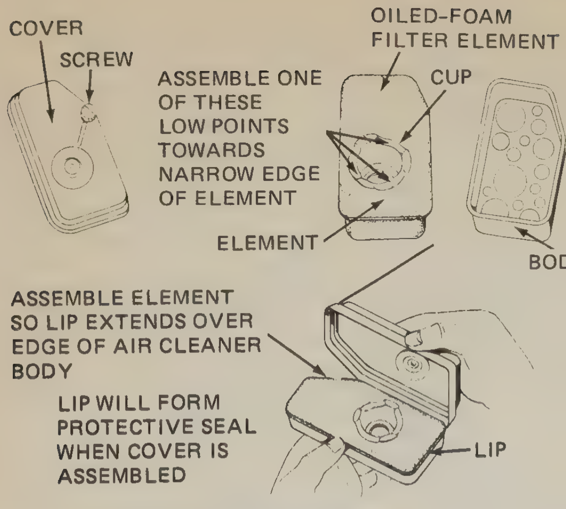
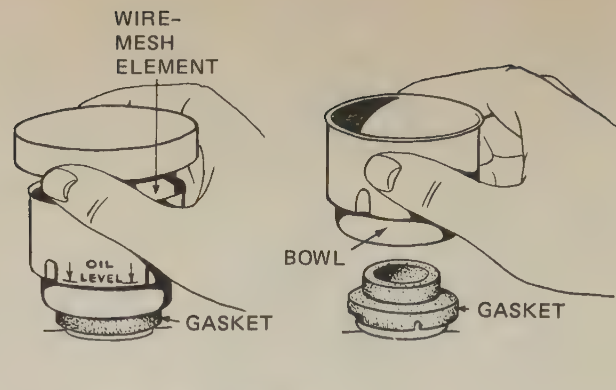


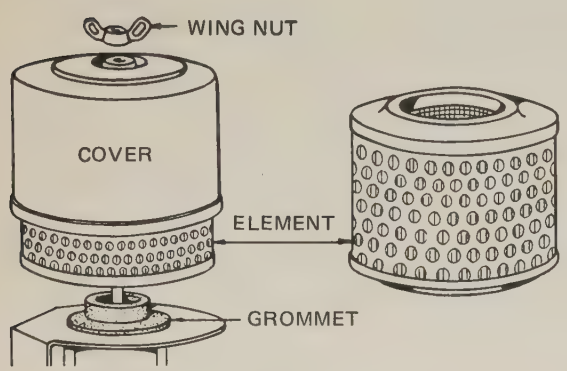
FIG. 17-4 Engine with a gravity-feed fuel system. *(Briggs & Stratton Corporation)*



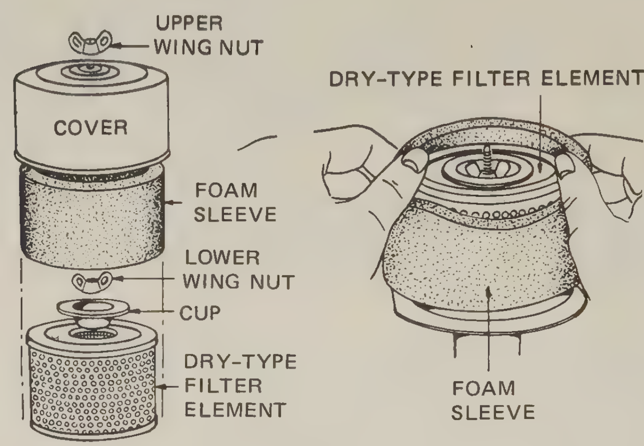
(*a*) OILED-FOAM AIR CLEANER



(*b*) OIL-BATH AIR CLEANER



(*c*) DRY-ELEMENT AIR CLEANER



(*d*) HEAVY-DUTY AIR CLEANER

FIG. 17-5 Various types of small-engine air cleaners. *(Briggs & Stratton Corporation)*

When the gasoline is at the proper height in the bowl, the needle valve is pressing tightly against its seat so that no more gasoline can enter. When the carburetor withdraws gasoline to operate the engine, then the gasoline level in the float bowl falls, the float and needle drop down, and more gasoline can enter. In operation, the needle valve holds a position

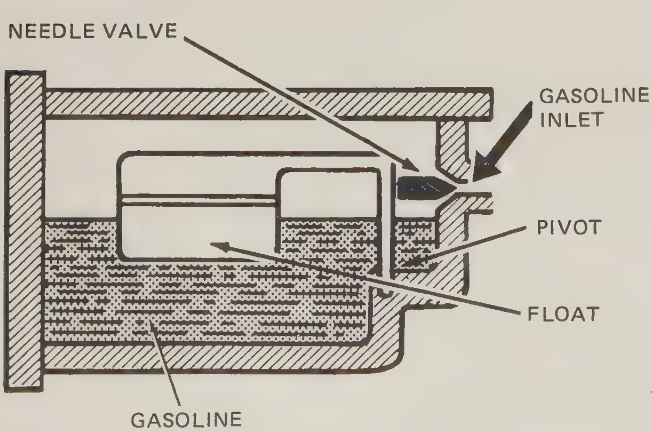


FIG. 17-6 Simplified drawing of a float bowl.

that allows gasoline to enter at the same rate that the carburetor withdraws it. This keeps the level of gasoline in the float bowl at the same height.

Not all carburetors for small engines have a float bowl. For example, a chain saw must be operated in many different positions, and a float bowl does not permit this. Therefore, chain saws and certain other small-engine-powered equipment use a type of carburetor that does not have a float bowl. In general, however, the basic parts and systems are the same in all carburetors.

○ 17-7 THE BASIC CARBURETOR The carburetor has three basic parts besides the float system. These are the air horn, the fuel nozzle, and a throttle valve (Fig. 17-7). The throttle valve is a round plate fastened to a shaft. When the shaft is turned, the throttle valve is tilted more or less in the air horn. The throttle valve can be tilted to allow air to flow through freely or be turned to block the passage of air. This is the basic control of engine speed and power. Turning the throttle valve allows more or less air-fuel mixture to enter the engine so the engine can produce more or less power.

The air horn has a restriction, or venturi, at the point where the nozzle enters it (Fig. 17-7). The pur-

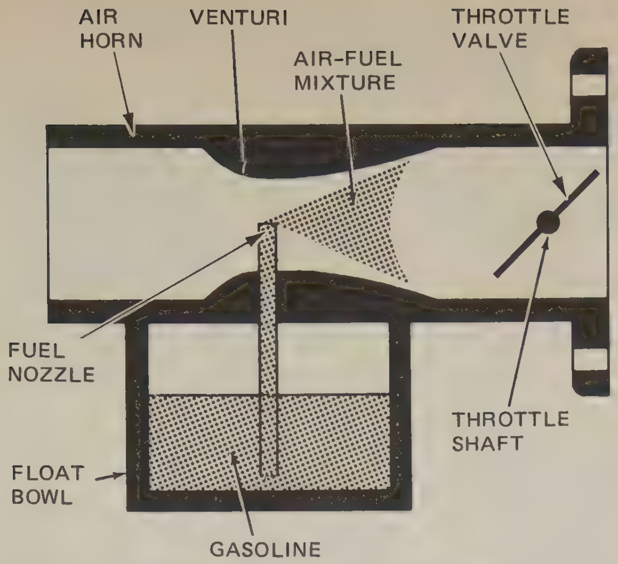


FIG. 17-7 If the air horn is turned to a horizontal position, the carburetor will work just as well.

pose of the venturi is to create a partial vacuum or low-pressure area when air is passing through the air horn.

The following is a simplified explanation of how the venturi creates a vacuum. As air moves into the air horn, all the air molecules are moving at the same speed and are about the same distance apart. But if all the molecules are to get through the venturi, they must begin to move faster as the air enters the venturi. As the first molecule enters the venturi, it speeds up, momentarily leaving the second molecule behind. The second molecule then enters the venturi and also speeds up. But the first molecule, in effect, has a headstart and the second molecule cannot catch up. Therefore, in the venturi, the molecules of air are farther apart.

Where molecules are relatively far apart, there is a partial vacuum, or low-pressure area. In the carburetor venturi, this vacuum is located around the end of the fuel nozzle. Then air pressure on the fuel in the float bowl pushes fuel up the tube and out the fuel nozzle (Fig. 17-8). The fuel sprays into the passing air, mixing with it to form the air-fuel mixture that the engine needs to operate.

The more air that passes through the air horn, the higher the vacuum at the venturi and the greater the amount of fuel that feeds from the fuel nozzle. Therefore, the proper proportions of air and fuel are maintained throughout the full range of throttle positions. When the throttle is partly opened, only a small amount of air flows through and only a small amount of fuel feeds from the fuel nozzle. But when the throttle is wide open, a large amount of air flows through the venturi and a large amount of fuel feeds from the fuel nozzle.

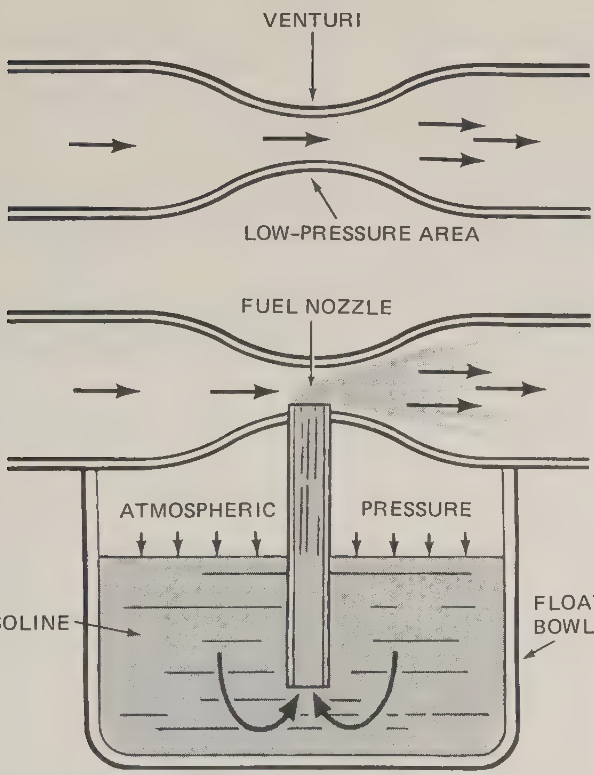


FIG. 17-8 (Top) The venturi produces a vacuum, or low-pressure area, when air flows through it. (Bottom) A nozzle leading up from the float bowl will pass gasoline upward into the air stream as atmospheric pressure pushes it up toward the vacuum. *(Lawn Boy Division Outboard Marine Corporation)*

○ 17-8 CARBURETOR ACTION

The carburetor mixes air and gasoline to provide the combustible air-fuel mixture the engine requires to run. This is shown in Fig. 17-7. As air passes through the carburetor on its way to the engine, gasoline is fed into it by a system we will describe later. The gasoline is fed into the passing air as a fine spray. This causes the gasoline to evaporate very quickly, producing the required combustible mixture of air and gasoline vapor.

Whenever a liquid is sprayed, it is turned into a great many tiny droplets. The effect is called atomization, because the liquid is broken up into small droplets. However, the liquid is not actually broken up into atoms as the name implies. Each droplet is exposed to air on all sides, and so it evaporates, or turns to vapor, very quickly. One fluid ounce [30 cc] of gasoline, broken up into fine droplets by spraying, will actually expose several square feet of surface area to the air. Therefore, vaporization, or evaporation, takes place almost instantly.

The carburetor shown in Fig. 17-7 is a horizontal carburetor. The air horn lies in the horizontal position. This is the type of carburetor used on many small engines and motorcycles. However, the air horn can be turned to a vertical position and the carburetor will work just as well. This type of carburetor is used on almost all automobile engines.

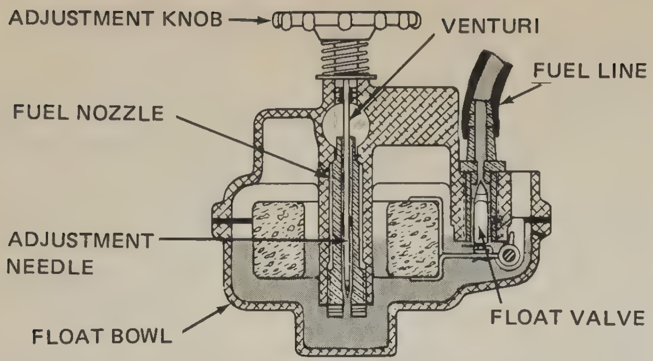


FIG. 17-9 Sectional view of a carburetor for a two-cycle engine used on a lawn mower. *(Lawn Boy Division of Outboard Marine Corporation)*

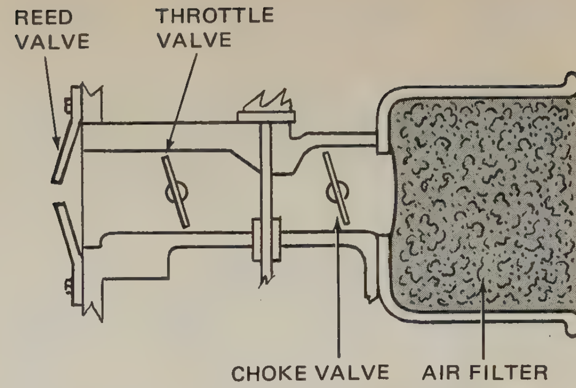


FIG. 17-11 The choke valve is located between the air filter and the venturi.

○ 17-9 ADJUSTING THE AIR-FUEL MIXTURE On some carburetors, the richness of the air-fuel mixture can be varied by turning an adjustment knob or screw to raise or lower the adjustment needle (Fig. 17-9). If the adjustment needle is lifted away from its seat, the fuel passage around the needle tip is enlarged and more fuel can flow. This means that there will be more fuel and that the air-fuel mixture will be richer. But if the adjustment knob or screw is turned to move the needle tip toward its seat, then the passage is smaller. Less fuel can flow (Fig. 17-10). Now the air-fuel mixture will be leaner.

○ 17-10 CHOKE VALVE The choke valve is located between the air filter and the carburetor venturi (Fig. 17-11). The purpose of the choke is to help start the engine. During starting, especially when the engine is cold, only part of the gasoline will evaporate to form a combustible mixture. This means that the carburetor nozzle must deliver more gasoline to the air passing through. The choke valve has this job. The choke valve is a round plate, like the throttle valve. When the choke valve is closed, it partially blocks the air horn so that less air can get through. This produces a partial vacuum in the air horn when the engine is cranked and the piston pulls air from the air horn. This partial vacuum, added to the vacuum caused by the venturi, results in a greater vacuum at the fuel nozzle. More fuel feeds from the fuel nozzle, and the resulting mixture is enriched. After the engine starts, the choke valve must be opened to prevent delivery of an excessively rich mixture to the running engine.

○ 17-11 PRIMER Many small-engine carburetors have a primer instead of a choke valve. One type is shown in Fig. 17-12. The primer, when operated, supplies extra fuel to the carburetor discharge holes. The type shown in Fig. 17-12 works this way: When you press down on the primer bulb, you shut off the vent hole and force air into the float bowl. This forces fuel up through the fuel discharge hole. The primer is also called a tickler.

Another primer which is actually a small pump is shown in Fig. 17-13. This primer has a cup-shaped disk on the bottom of a spring-loaded rod. When the plunger is pushed down, fuel passes around the edge of the disk, as shown in Fig. 17-13*b*. Then, when the plunger is released, the spring pulls it up. This lifts fuel upward into the carburetor, as shown in Fig. 17-13*c*. The fuel pours out into the carburetor air horn.

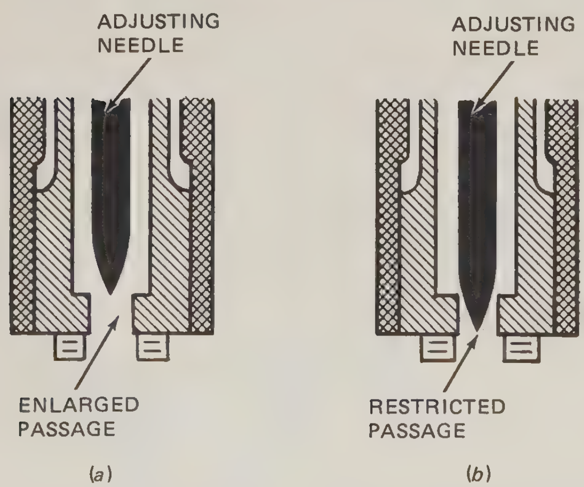


FIG. 17-10 *(a)* Carburetor adjustment needle and seat showing enlarged passage allowing more fuel to flow. *(b)* Restricted passage allowing less fuel to flow.

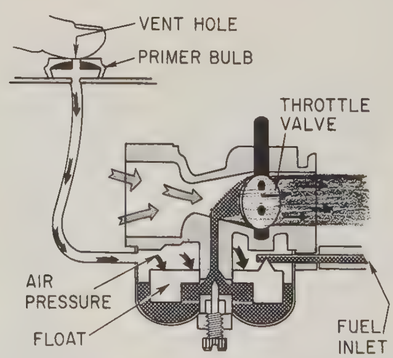


FIG. 17-12 Bulb-type primer. When the primer bulb is pressed down, it pushes air into the carburetor float bowl, causing the float bowl to discharge fuel into the airstream through the carburetor.

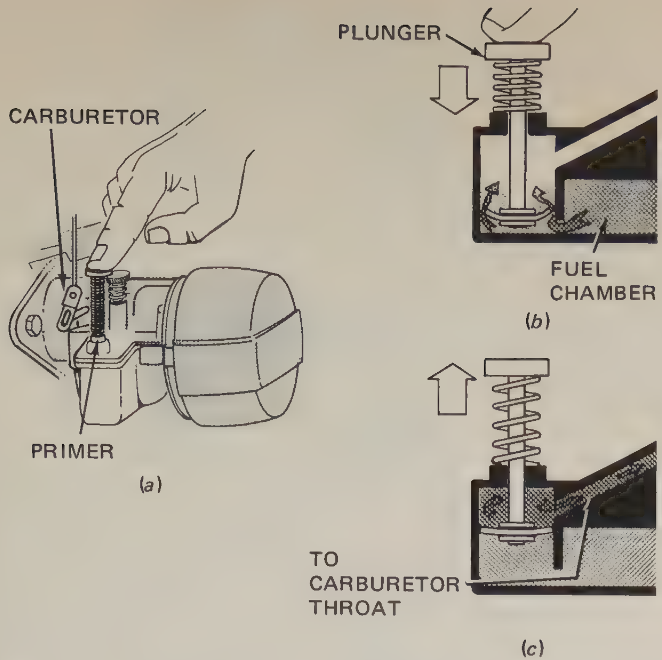


FIG. 17-13 Primer for a small engine. When the plunger is pushed down as at *(b)*, fuel passes by the cup-shaped disk. Then, when the plunger is released as at *(c)*, the spring raises the disk and lifts fuel up into the carburetor.

When the engine is cranked, the air passing through will be enriched for easier starting.

○ 17-12 GRAVITY-FEED FUEL SYSTEM In the gravity-feed fuel system, shown in Figs. 17-1, 17-2, and 17-4, the fuel tank is located above the carburetor. The fuel feeds down to the carburetor float bowl by gravity. Figure 17-14 shows a sectional view of a carburetor used with this type of system. Fuel flows downward by gravity from the fuel tank to the float bowl when the fuel level is low in the float bowl.

The carburetor works just about the same as the carburetors used in automobiles. However, the small-engine carburetor is simpler in basic design and does not have an accelerator pump, a power system, and so on. The type shown in Figs. 17-4 and 17-14 has a choke valve in the air horn. When the choke valve is closed, a high vacuum develops during cranking so that more fuel feeds into the engine. The mixture becomes very rich for easy starting. When the throttle is opened and the engine is running, as shown in Fig. 17-14, fuel feeds past the needle valve and upward through the nozzle so that the passing air is charged with fuel. During idle, with the throttle closed, the relatively high vacuum above the throttle plate causes fuel to feed on upward through the nozzle and into the opening back of the idle valve. From there, the fuel discharges into the air passing above the throttle plate.

○ 17-13 SUCTION-FEED FUEL SYSTEM In the suction-feed system (also called the suction-lift system), the fuel tank is below the carburetor. Fuel feeds upward directly from the fuel tank to the carburetor discharge holes. No separate float bowl is needed. Figure 17-15 illustrates how this carburetor works. Figure 17-16 is a cutaway view of an actual suction-feed carburetor. The fuel pipe from the fuel tank is connected to the two discharge holes below the point where the needle valve is located. In operation, the partial vacuum produced by the passage of air through the air horn causes atmospheric pressure to push fuel upward from the fuel tank and out through the discharge holes. The throttle plate (in Fig. 17-15) has a notch cut out of it at the top. This is for idle operation. When the throttle plate is closed, the only passage for the ingoing air is through this notch. The passing air produces a sufficient vacuum close to the idle discharge hole to cause fuel to flow. This ensures that the idle mixture contains sufficient fuel.

Some models of suction-feed carburetors have a ball check in the fuel pipe, as shown in Fig. 17-16. The purpose of the ball-check valve is to prevent fuel in the pipe from flowing back down into the fuel tank when the engine stops. This improves subsequent starting, because the fuel pipe is already filled. Therefore, it begins to feed fuel just as soon as the engine crankshaft is spun.

The choke used in the carburetor shown in Figs.

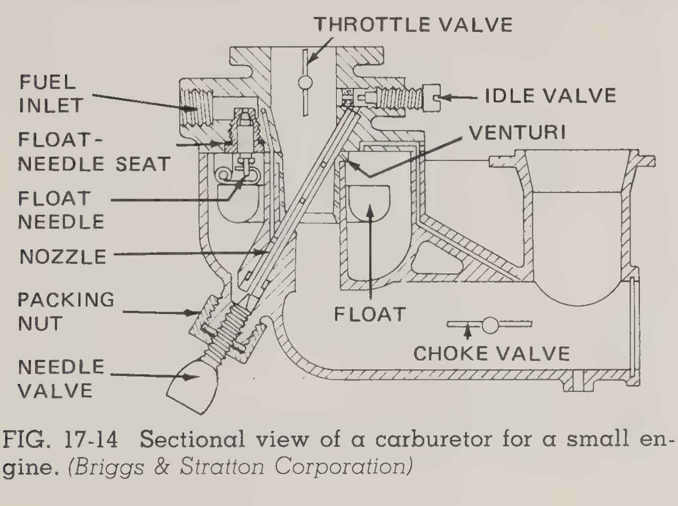


FIG. 17-14 Sectional view of a carburetor for a small engine. *(Briggs & Stratton Corporation)*

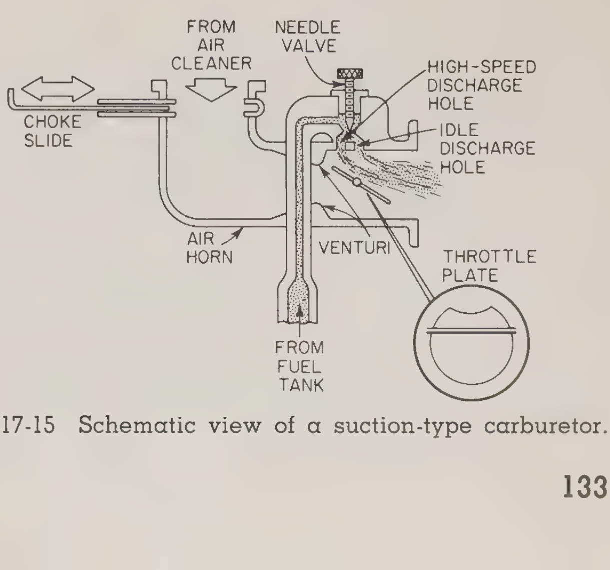


FIG. 17-15 Schematic view of a suction-type carburetor.

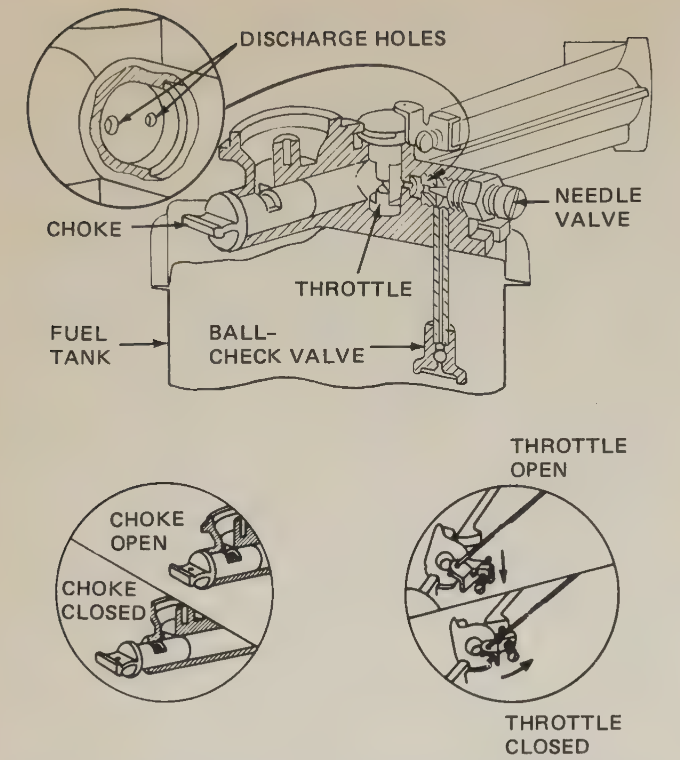


FIG. 17-16 Cutaway view of a suction-type carburetor. Note the round slide-type carburetor choke to the lower left. *(Briggs & Stratton Corporation)*

17-15 and 17-16 is the slide type. It can be slid into the air horn to restrict air flow and thereby increase the vacuum at the discharge holes. This produces additional fuel feed during cranking so that an adequately rich mixture is delivered to the engine.

Figure 17-15 illustrates a suction-type carburetor that has a flat slide-type choke. The carburetor in Fig. 17-16 has a round slide-type choke.

○ 17-14 SUCTION-FEED CARBURETOR WITH SINGLE CONTROL One model of suction-feed carburetor uses a single control valve which provides for choking, running, and stopping the engine. A carburetor of this type is shown in Fig. 17-17 with the three positions of the valve indicated. The valve is in the

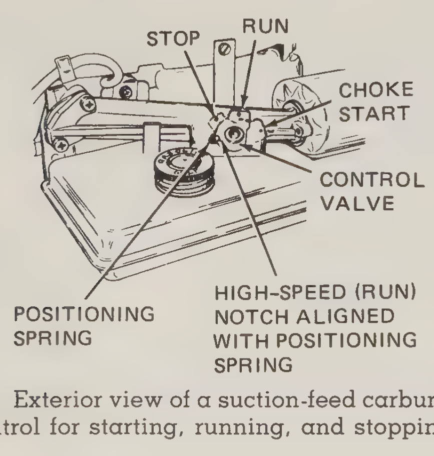


FIG. 17-17 Exterior view of a suction-feed carburetor with a single control for starting, running, and stopping.

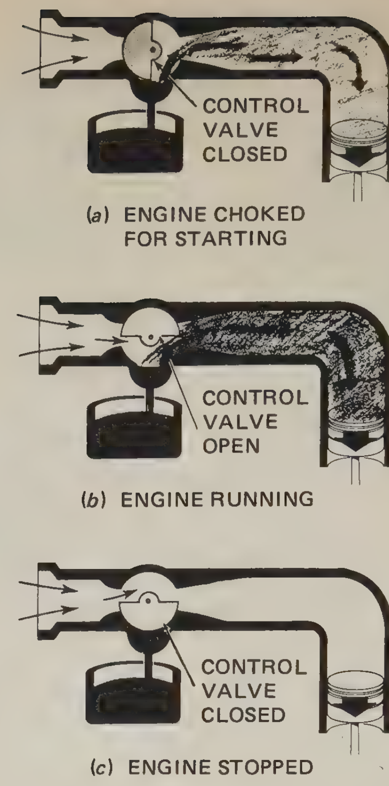


FIG. 17-18 For starting, the control valve is closed and so the engine is choked. When the engine starts, the control valve is turned to the running position, and this leaves the control valve out of the way so that air and fuel can feed into the engine. To stop the engine, the control valve is turned to the closed position, so that the fuel passage from the fuel tank is closed off.

shape of a half cylinder set in a hollow cylinder, as shown in Fig. 17-18. The valve can be rotated into the three positions to provide for engine control. When the control valve is positioned as shown in Fig. 17-18*a*, the air flow through the carburetor is choked off. Therefore, a high vacuum will develop on the intake stroke as the engine is cranked. This high vacuum will cause a heavy flow of fuel from the tank so the engine receives a rich mixture for starting.

After the engine has started, the control valve is turned to the position shown in Fig. 17-18*b*. Now it is up out of the way, and normal engine operation results. Then, when the engine is shut off, the control valve is turned to the position shown in Fig. 17-18*c*. In this position, the fuel pipe from the fuel tank is blocked off and no fuel can reach the carburetor.

○ 17-15 SUCTION-FEED CARBURETOR WITH DIAPHRAGM The suction-lift, or suction-feed, carburetor described in the previous section works satisfactorily for the smaller engines of ½ to 3 horsepower. It does not work well for larger engines. The reason is that the vacuum will not provide sufficient fuel when the tank is nearly empty. It is easier for the vacuum to lift fuel up to the carburetor when the tank is full. But when the fuel tank is nearly empty, the fuel must be

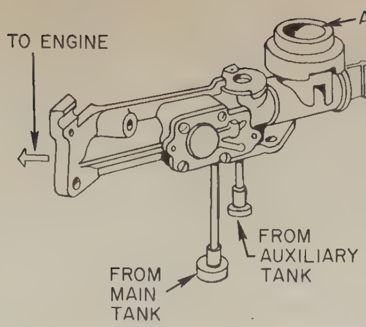


FIG. 17-19 Exterior view of a suction-feed carburetor with a diaphragm. *(Briggs & Stratton Corporation)*

raised considerably farther. Therefore, less fuel will be fed into the air passing through the carburetor. To provide for a more nearly even fuel feed, many suction-feed carburetors for larger engines have an auxiliary fuel tank or reservoir. It is very similar to the float bowl in carburetors previously described.

Figure 17-19 shows a carburetor of this type with the fuel tanks removed. There are two separate fuel pipes: one from the main fuel tank and one from the auxiliary tank. The arrangement is shown schematically in Fig. 17-20. Just above the main fuel tank there is a fuel pump that is operated by engine vacuum. When the piston is moving down on the intake stroke, the vacuum pulls air from the small chamber in which the pump spring is located. The pump diaphragm is pulled upward. This produces a vacuum under the diaphragm. Atmospheric pressure on the fuel in the main fuel tank then forces fuel up through the fuel pipe, as shown by the arrow in Fig. 17-20. The inlet valve is opened by the vacuum, and at the same time the outlet valve is closed by the vacuum. Fuel flows into the pump chamber. Now, when the intake stroke is completed, vacuum is lost in the carburetor. The spring can then push the pump diaphragm down. The pressure from the spring closes the inlet valve and opens the outlet valve, as shown in Fig. 17-21. As

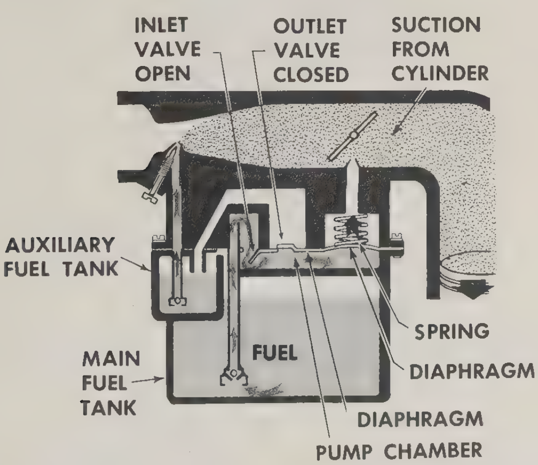


FIG. 17-20 Schematic sectional view showing the actions taking place in the diaphragm-type suction-feed carburetor when the piston is moving down.

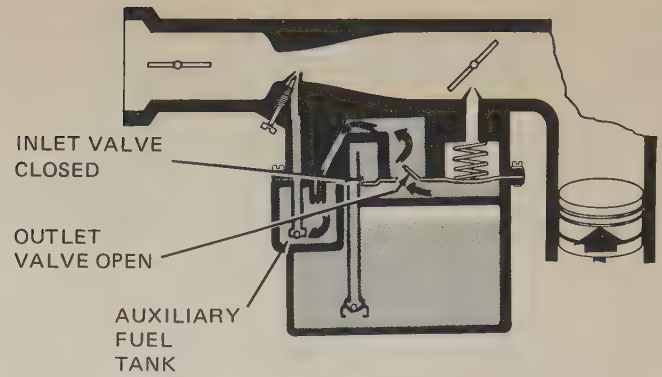


FIG. 17-21 Schematic sectional view of a diaphragm-type suction-feed carburetor, showing the actions when the piston is moving up.

a result, the pressure can push fuel from the pump chamber upward and into the auxiliary tank. This action keeps the auxiliary tank filled so that adequate fuel can be fed in a uniform manner into the carburetor. The fuel flow is unaffected by the level of fuel in the main fuel tank.

The intake stroke of the piston produces the vacuum that causes the pump to work. This description fits the four-cycle engine. On two-cycle engines, the vacuum is developed when the piston is moving up on the compression stroke. The vacuum is produced in the crankcase, and the air-fuel mixture from the carburetor feeds into the crankcase past the reed valve. This vacuum operates the diaphragm of the pump. The principle of operation is the same as for the four-cycle engine.

○ 17-16 DIAPHRAGM CARBURETOR This carburetor is required for engines that are operated at various angles. The carburetors discussed previously would not work with a chain saw, which is held at different angles when it is used. These other carburetors depend for their operation on a float bowl in the carburetor or on a fuel tank under the carburetor. The float-bowl type of carburetor has a means of keeping the float bowl filled with fuel to the proper level at all times. The tank type of carburetor, which uses suction to lift the fuel to the carburetor, must have the fuel tank under the carburetor. If either of these engines were held at an angle, the fuel would run out and the engine would either be starved for fuel or be fed so much fuel it would flood and die.

Some other type of carburetor must be used with engines that operate at various angles and in different positions. The diaphragm carburetor is the solution. It will provide uniform fuel feed to the engine regardless of the working position of the engine. A diaphragm carburetor is shown in simplified view in Fig. 17-22. When the piston moves down in a four-cycle engine during the intake stroke, or when it moves up in the two-cycle engine, a partial vacuum is produced in the carburetor air horn. This causes fuel

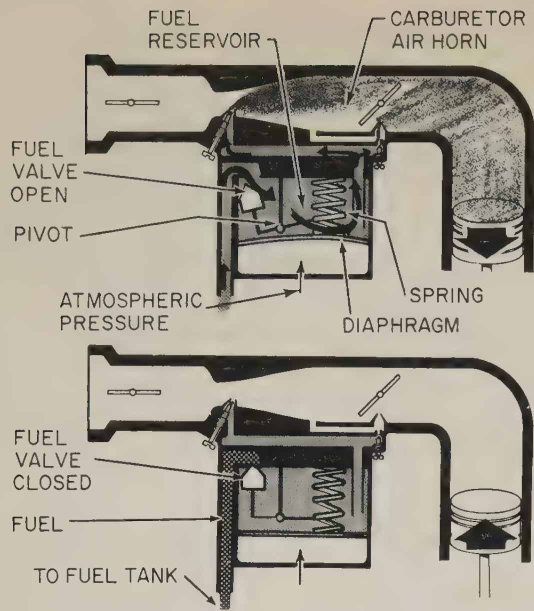


FIG. 17-22 Schematic view of a diaphragm carburetor. (Top) Actions when piston is moving down on intake stroke (four-cycle engine). (Bottom) Actions when piston is moving up.

to discharge from the fuel reservoir into the carburetor air horn. The partial vacuum also causes the diaphragm to move up against spring tension. Then, when the vacuum is lost (when the piston stroke ends), the spring pushes the diaphragm down. This creates a partial vacuum in the fuel reservoir. Atmospheric pressure then pushes fuel from the fuel tank into the reservoir to replenish the fuel withdrawn during the piston intake stroke. The action continues as long as the engine operates, providing the fuel needed to keep the engine running. Figure 17-23 shows a diaphragm carburetor.

○ 17-17 PRESSURE-FEED FUEL SYSTEM On engines where the fuel tank must be mounted on a level with or below the carburetor, a gravity-feed system will not work. A suction-feed system is often not satisfactory, because it works only for small engines. A fuel pump will deliver fuel to the float bowl of the carburetor regardless of the relative positions of fuel tank and float bowl. Fuel pumps are used on all automobiles. The purpose of the fuel pump is to withdraw fuel from the fuel tank and pump it into the carburetor float bowl. This keeps the float bowl filled to the proper level at all times.

The system using a fuel pump is called a pressure-feed system. A system of this type is shown in Fig. 17-3. A cam, or an eccentric, on the engine crankshaft forces a pump lever to move up and down. This action produces the pumping action in the pump. In larger engines, such as those used in automobiles, the pump lever is actuated by an eccentric on the engine camshaft, instead of the crankshaft. However, the principle of operation is the same.

Figure 17-24 shows schematically how the fuel pump works. When the pump lever is pushed down by the lobe on the cam, it lifts the diaphragm against the pressure of the diaphragm spring. This produces a vacuum in the pump chamber which lifts both the inlet and the outlet valves. The upward movement of the outlet valve closes it. The upward movement of the inlet valve opens it so that the vacuum will allow fuel from the fuel tank to flow into the pump chamber. This is shown by the arrow in the top illustration of Fig. 17-24.

When the lobe of the cam moves out from under the pump lever, the diaphragm spring pushes down on the diaphragm. This creates pressure in the pump chamber (Fig. 17-24, bottom). The pressure pushes down on both valves, causing the inlet valve to close and the outlet valve to open. The pressure then pushes fuel from the pump chamber into the carbu-

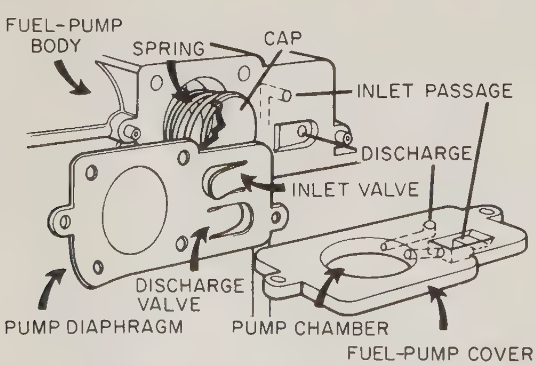


FIG. 17-23 Partial disassembled view of a diaphragm carburetor showing the details of the pump diaphragm. *(Briggs & Stratton Corporation)*

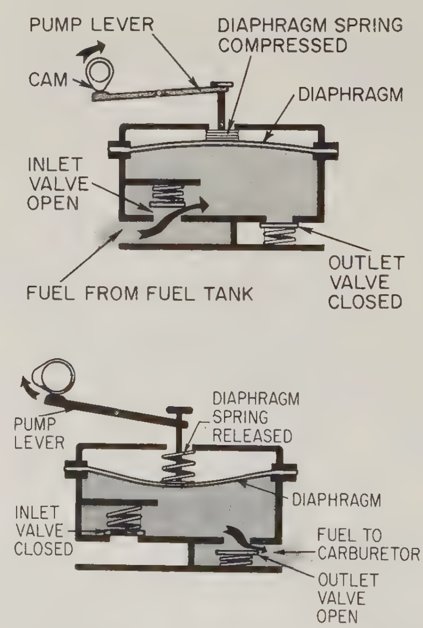


FIG. 17-24 (Top) Action in the fuel pump when the pump lever is pushed down by the cam lobe on the eccentric. (Bottom) Action in the fuel pump when the lobe has moved out from under the pump lever.

retor float bowl. The action is continuous as long as the engine runs. When the float bowl in the carburetor becomes sufficiently filled, the float rises and lifts the needle valve up into the seat. This shuts off any further delivery of fuel. We have already described how this works and showed a simplified float system in Fig. 17-6. When this float system refuses to take any further fuel, the diaphragm remains in its upper position, shown in Fig. 17-24 (top), even though the pump lever releases it and the spring pressure is trying to push it down.

○ 17-18 GOVERNORS Where the load on the engine varies but a steady speed is required, such as on a lawn mower, an engine governor is needed to prevent the engine from bogging down under heavy load. Basically, what the governor does is control the opening of the carburetor throttle valve. When the load is light, the engine starts to speed up. As this happens, the governor causes the throttle valve to move toward the closed position. This counterbalances the speedup tendency so that the engine speed remains constant. Likewise, if the load increases, as, for example, when the mower meets some high weeds or tough grass, then the engine tends to slow down. When this happens, the governor causes the throttle valve to open so that more air-fuel mixture enters the engine. The engine will then develop more power to handle the heavier load without slowing down.

There are two general types of governor: the air-vane type and the centrifugal type. The air-vane type works on the flow of air from the blades on the flywheel. The centrifugal type is operated by a centrifugal device which is actuated by engine speed.

○ 17-19 AIR-VANE GOVERNOR The air vane is located under the flywheel shroud close to the flywheel, as shown in Fig. 17-25. This places the air vane in the path of the air coming off the flywheel blades. The air vane is connected by linkage to the throttle valve, as shown in Fig. 17-25. When the air vane is moved, the throttle valve will open or close. There also is a spring in the linkage, which tends to pull the throttle into the opened position. When the engine is stopped, the throttle valve is open.

When the engine is running, a flow of air from the flywheel blows against the air vane, pushing it toward the right (in Fig. 17-25). As the air vane moves, the linkage tends to close the throttle. The faster the engine rotates, the stronger the air blast from the flywheel grows and the farther the air vane moves. Therefore, the engine cannot overspeed, because the air-vane governor will close the throttle sufficiently to prevent it.

To take a typical example, suppose you are using a power lawn mower. You start the engine and set the throttle to run at 3000 revolutions per minute (rpm).

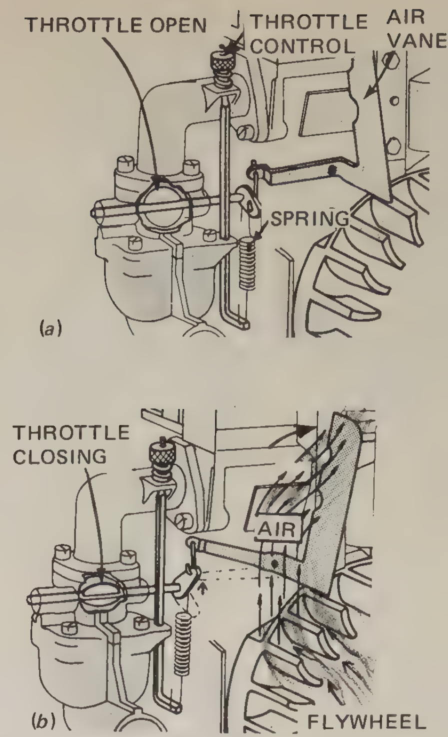


FIG. 17-25 Details of an air-vane type governor. *(a)* When the engine is not running, the spring holds the throttle open. *(b)* When the engine is running, air from the blades on the rotating flywheel causes the vane to move, thereby partly closing the throttle.

You wait for a few seconds to allow the engine to warm up. The engine is running without load and tends to speed up. As it speeds up beyond the preset 3000 rpm, the air vane moves enough to partly close the throttle, preventing overspeeding. Now, with the engine warmed up, you start across the lawn. You hit a heavy patch of grass, and this puts an extra load on the engine. The engine speed starts to drop. Now the air vane has less air blowing against it, and it is pulled back by the spring tension. This movement allows the throttle to open farther, feeding more air-fuel mixture to the engine. The engine responds by producing more power to handle the heavier load.

○ 17-20 CENTRIFUGAL GOVERNOR The centrifugal governor has a lever that is linked to the throttle through an arm and a rod (Fig. 17-26). Figure 17-27 shows how the governor works. As engine speed increases, the two flyweights move out and push against the spool. This motion is carried to the arm so that the rod pulls down on the throttle lever and tends to close the throttle. When the engine is started, the operator opens the throttle to get the engine speed desired. This puts a certain tension on the control spring, and the throttle is opened through the pull of the spring on the governor arm. This gives the engine the preset speed that the operator wants. Now, if the engine tends to speed up, the governor arm is turned, as shown to the right in Fig. 17-27. This tends to close

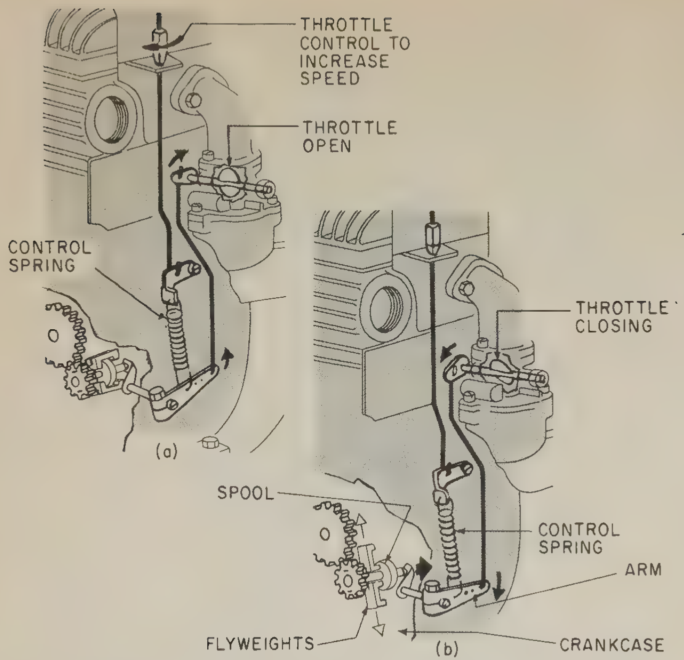


FIG. 17-26 Details of a centrifugal governor. *(a)* When the engine is not running, the spring holds the throttle open and also holds the spool at the "in" position so that the flyweights are retracted. *(b)* When the engine runs, the flyweights move out, and this causes the throttle to partly close.

the throttle to prevent overspeeding. If the engine tends to slow down because of a heavy load, the flyweights move inward to allow the throttle to open wider. This allows the engine to produce more power. Therefore, the engine maintains the speed at which the operator has set the throttle.

Instead of flyweights in the governor, some governors have flyballs (Fig. 17-28). The flyballs are located under a curved plate. As engine speed increases, the flyballs tend to move outward. This causes them to press against the angled part of the plate, raising the plate. As the plate is raised, it also raises the spool. The spool, which is linked to the

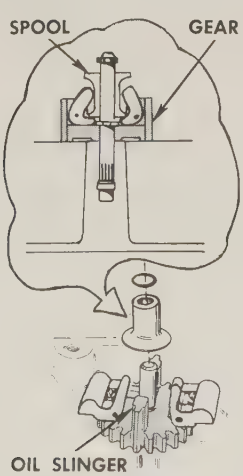


FIG. 17-27 Details of the centrifugal governor using flyweights.

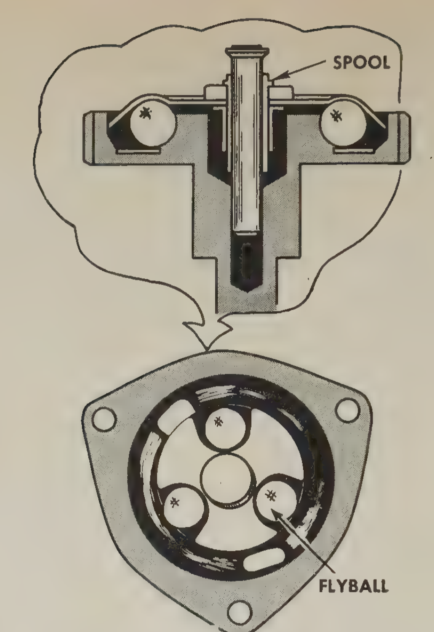


FIG. 17-28 Details of the centrifugal governor using flyballs.

throttle, then causes the throttle to partly close. This prevents overspeeding of the engine.

Most small engines should be operated in the high-speed range. At high speed, the engine has the capacity to adjust to a wide range of power demands. If the throttle setting is high enough, the engine is ready to start pulling hard the instant the governor calls for more power. If the throttle setting is too low, there is not enough tension on the control spring to allow the engine to start putting out full power quickly.

NOTE: The governor should never be adjusted to allow the engine to run above rated speed. Even though the engine might temporarily operate at the excessive speed and temporarily handle excessively heavy loads, it would quickly wear out. Never operate an engine having an air-vane governor with the engine shroud removed. With the shroud off, the air flow from the flywheel is not directed against the air vane. As a result, there is no governor control. The engine could greatly overspeed and tear itself to pieces.

A typical centrifugal governor used on a lawnmower engine is shown in Fig. 17-29. In this governor, the lower collar is fastened to the crankshaft. The upper collar is attached to the lower by a pair of pivoted links. A spring holds the two collars apart. When the engine runs, the pivoted links move out owing to centrifugal force. This action moves the upper collar down toward the lower, partly compressing the spring. The faster the engine runs, the greater the centrifugal force on the pivoted links becomes and the farther down the upper collar moves by further compressing the spring. The upper collar is

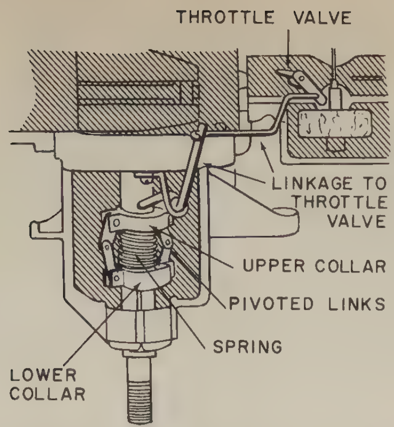


FIG. 17-29 Sectional view of lower part of the engine, showing details of the governor and the linkage to the throttle valve. *(Lawn Boy Division of Outboard Marine Corporation)*

connected by linkage to the carburetor throttle valve. As the upper collar moves up or down, it opens or closes the throttle valve. If the engine slows down, for example, because of heavy loads, then the collar starts to move up. This causes the throttle valve to open and supply additional air-fuel mixture to the engine so it can produce added power. If the engine starts to speed up, the collar moves down to cause the throttle valve to partly close and reduce the amount of air-fuel mixture to the engine. This governor action is shown in Fig. 17-30.

There are other types of governors. Some are mounted at the upper end of the crankshaft, above the magneto. However, all governors work in a similar manner.

○ 17-21 EXHAUST SYSTEM After the air-fuel mixture has been burned in the engine cylinder, the burned exhaust gases are forced out of the cylinder and into the exhaust port. From there they pass through the muffler and into the open air. Figure 11-17 shows the muffler in place on a small engine.

The muffler provides a series of passages and chambers through which the exhaust gases must pass before being discharged into the air (Fig. 17-31). These passages and chambers muffle the exhaust noise, quieting the engine.

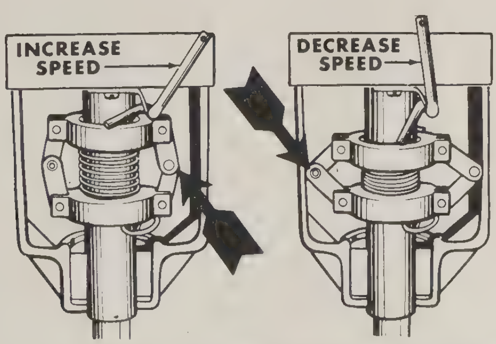


FIG. 17-30 As the engine speed increases, the pivoted links fly out, causing the control arm to move the throttle valve toward a closed position. *(Lawn Boy Division of Outboard Marine Corporation)*

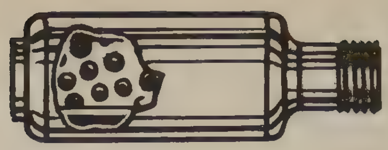


FIG. 17-31 Cutaway view of a small-engine muffler, which threads into the exhaust-port opening.

REVIEW QUESTIONS

1. What are the three types of small-engine fuel systems?
2. What are the parts in the small-engine fuel systems?
3. Explain how a gravity-feed fuel system works.
4. Name the main parts of a typical small-engine carburetor.
5. What is the purpose of the fuel tank?
6. What is the purpose of the air cleaner?
7. Why is a fuel filter needed?
8. What is carburetion?
9. What is vaporization?
10. What is atomization?
11. What are the three basic parts of the simple carburetor?
12. Describe the venturi effect.
13. What forces the fuel up out of the fuel nozzle and into the air passing through the carburetor air horn?
14. Describe the operation of the carburetor float system.
15. Describe the operation of the carburetor fuel system.
16. How is the air-fuel mixture adjusted on some carburetors?
17. What is the purpose of the choke?
18. What is the difference between a primer and a choke?
19. What is the difference between a gravity-feed fuel system and a suction-feed fuel system?

20. What is a common application for a diaphragm carburetor?

21. Which type of fuel system has a fuel pump?

22. What is a governor?

23. Why is a governor needed?

24. Name two types of governors.

25. What part on the engine has the job of reducing exhaust noise?

SELF PROJECT

Examine as many different carburetors as you can. When you examine each carburetor, take a separate sheet of paper to write down the facts about it. At the top of the sheet, write the make and model of engine from which the carburetor came, and also the model and type of carburetor.

Note the location of the venturi, main nozzle or nozzles, throttle plate or plates, and so on. Identify all the openings in the air horn.

18 Chapter

Fuel-System Service

After studying this chapter, you should be able to:

1. **List the safety cautions to be followed when servicing fuel systems**
2. **Demonstrate how to service each type of air cleaner**
3. **Demonstrate how to service each type of fuel filter**
4. **Explain what could happen if the crankcase breather is not serviced regularly**
5. **Demonstrate how to adjust a carburetor**
6. **Describe the procedures to adjust each type of governor**

○ 18-1 AIR-CLEANER SERVICE Carburetor air cleaners for small engines can be classified as oil-bath, oiled-foam, and dry-element. These are shown in Fig. 17-5. In the oil-bath cleaner, shown in Fig. 17-5*b*, there is an oil cup in the bottom of the cleaner. Incoming air passes over the oil in the oil cup and picks up a fine mist of oil, which is carried up to the metal-mesh filter element. Dust particles are trapped by the oily surfaces, and the oil washes them down into the oil cup. In the oiled-foam cleaner, shown in Fig. 17-5*a*, the filter element consists of a polyurethane-foam pad, soaked in oil. The air must pass through the foam, and dirt particles are trapped by the oily surfaces as they pass.

The dry-element cleaner, shown in Fig. 17-5*c*, has a paper-type or fiber filter element through which the air must pass. The paper is of a very special type with extremely small pores, or openings, through which the air can pass. These tiny holes will not permit dust particles to pass, so dust is trapped on the surface of the filter element.

Regardless of the type of air cleaner, the usual recommendation is that air cleaners be serviced after every 25 hours of service. If the engine is operated under extremely dirty or dusty conditions, then the air cleaner should be serviced more often—as many as two or three times a day! The procedures for cleaning all three types of air cleaners follow.

Oil-Bath Air Cleaner To remove an oil-bath air cleaner, disconnect the spark-plug wire to make sure the engine will not start. The air cleaner will be secured either by a bail wire, by screw threads on the filter element itself, or by a wing nut. The air cleaner can be removed by taking off the bail wire or wing nut, or by unscrewing the filter element as shown in Fig. 18-1. If there is any chance that dirt or dust might fall into the carburetor, cover the opening with a clean cloth or plastic film.

After the air-cleaner parts have been removed,

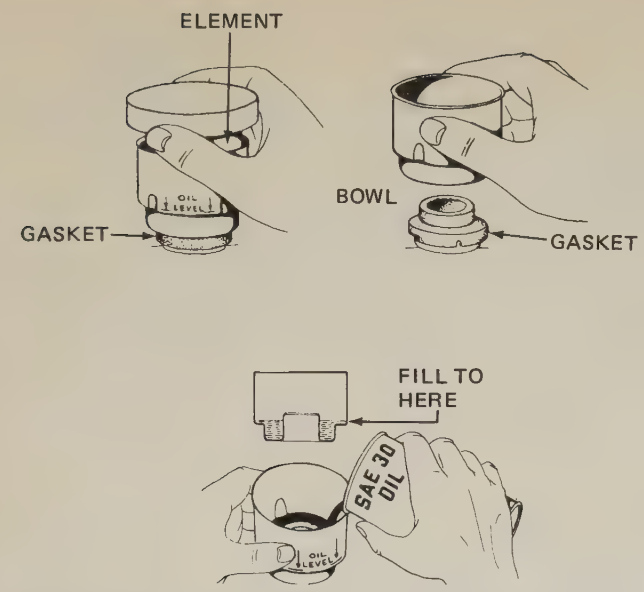


FIG. 18-1 Removing oil-bath air cleaner for cleaning and replacement of the oil. *(Briggs & Stratton Corporation)*

separate them and pour out the old oil. Clean the oil cup, filter, and cap with solvent and a brush, as shown in Fig. 18-2. Be sure to remove any caked dirt in the bottom of the oil cup. Refill the cup to the oil-level mark with the oil specified—usually SAE 30—shown in Fig. 18-1.

Examine the condition of the air-cleaner gasket. If the gasket is damaged, it should be replaced. Then reinstall the oil cup and filter element.

Oiled-Foam Air Cleaner These are held in place by a snap-on cover, a wing nut, or a screw. A typical oiled-foam air cleaner is shown in Fig. 17-5*a*. The steps in servicing an oiled-foam filter are shown in Fig. 18-3. To service this type of air cleaner, remove it from the engine. Then wash the filter element in detergent and water. Squeeze the foam repeatedly with your hands, as shown in Fig. 18-3, to get out all the old oil and dirt.

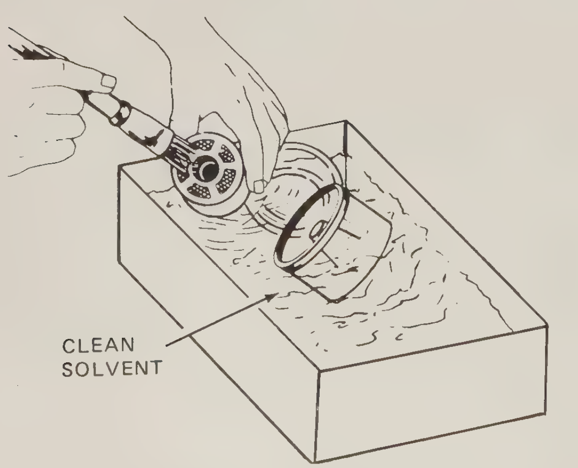


FIG. 18-2 Cleaning oil-bath oil cleaner in solvent.

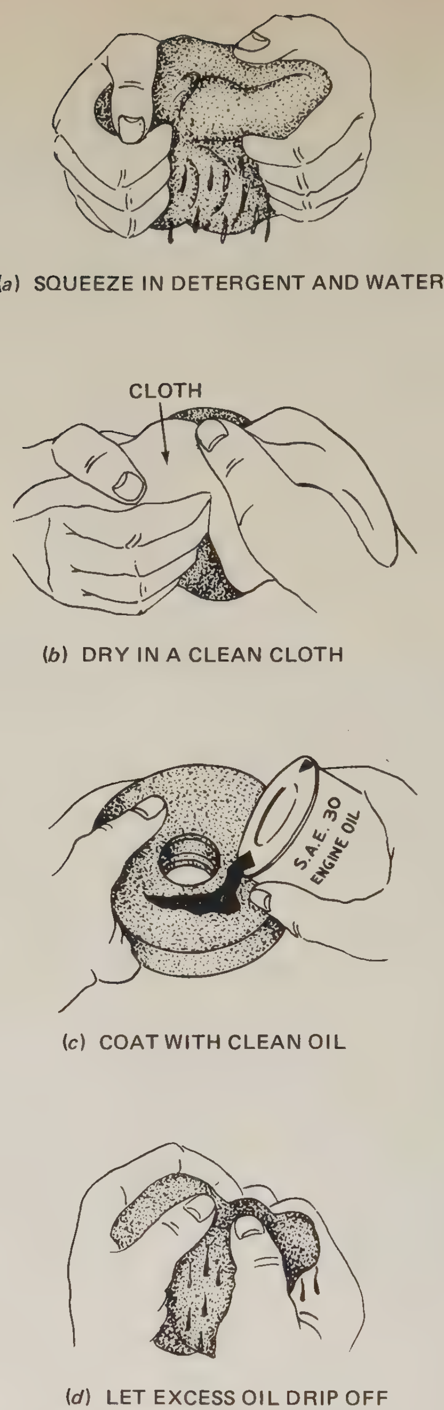


FIG. 18-3 Steps in servicing an oiled-foam filter element. *(Briggs & Stratton Corporation)*

Wrap the foam in a clean cloth, and squeeze the foam until it is dry. This is shown in Fig. 18-3*b*. Coat the foam with fresh clean SAE 30 engine oil. Finally, squeeze the foam between your hands and let the excess oil drip off. Failure to do this may cause the excess oil to choke the engine, and it may fail to start.

The metal-mesh element is cleaned by washing in solvent, as shown in Fig. 18-2. It is dried by blowing compressed air through it or swishing it in the air several times, as shown in Fig. 18-4. It should be dipped in engine oil to recoil it.

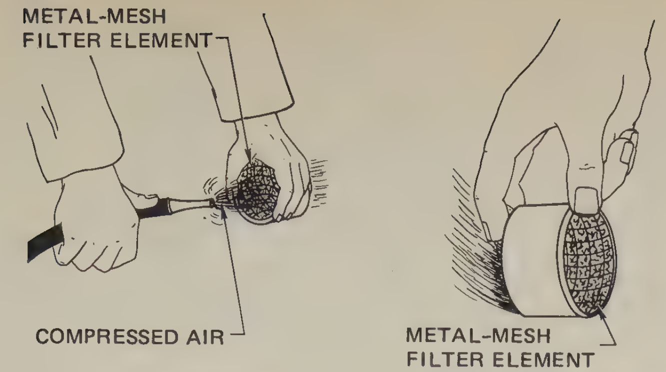


FIG. 18-4 Cleaning and drying the metal-mesh filter element.

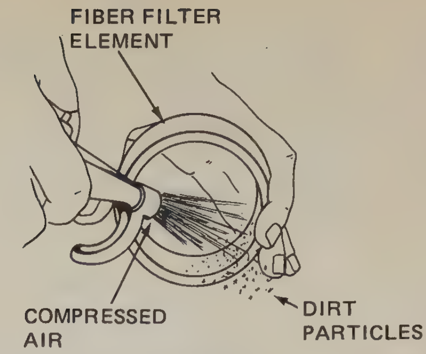


FIG. 18-6 Using compressed air to clean the fiber-type filter element. Note that the compressed air is blown from inside out, or in the direction opposite to the air flow during air-cleaner operation.

Reinstall the filter element and air cleaner-assembly. Some polyurethane elements have a coarse filter on the outside and a fine filter on the inside. When installing this type, make sure that the coarse side faces out.

Dry-Element Air Cleaner Remove the filter-element cover if it is a separate part. Some air cleaners of this type are made in one piece without a separate cover. Cover the carburetor intake with a cloth or plastic film. The paper filter element can be cleaned by tapping it lightly on a flat surface, as shown in Fig. 18-5. Do not wash a dry filter, unless the manufacturer's instructions specify doing so. Wetting the paper will clog the paper pores and ruin the element. If the dust does not drop off easily, or if the element is damaged, throw it out and install a new element. Even one pin hole in the paper element can let in enough dust to wear out the engine prematurely.

If the element is fiber or moss, clean it by blowing compressed air through from the inside, as shown in Fig. 18-6. Wash it in soap and water. Do not use an oily solvent, because it could clog the element and prevent air from passing through.

On any type of air cleaner, be sure that its mounting gasket is in good condition and provides a tight seal between the air cleaner and the carburetor intake. A leaking seal will allow unfiltered air to enter the engine. This means that dirt will get into the engine.

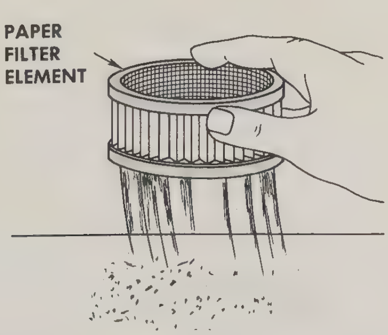


FIG. 18-5 Tapping the paper filter to knock dirt loose.

○ 18-2 FUEL-FILTER SERVICE There are three general types of fuel filters, or fuel strainers. One type has a separate detachable sediment bowl that usually is made of glass. This type of fuel filter is shown in Fig. 18-7. A second type of fuel filter is a strainer. It attaches to the end of a flexible hose which is inserted inside the fuel tank, as shown in Fig. 18-9. This is the type of fuel strainer used on engines that must operate in any position, such as chain saws. Regardless of the position of the fuel tank, the weighted strainer will fall to the low part of the tank, where the fuel is. The end of the hose always will be covered by fuel.

To clean the sediment-bowl type of fuel strainer, shown in Fig. 18-7, close the shut-off valve which is used with the gravity-feed fuel system. This will prevent fuel from flowing out of the fuel tank while the bowl is off. Loosen the thumb nut on the wire bail, and swing the wire bail to one side. Remove the bowl

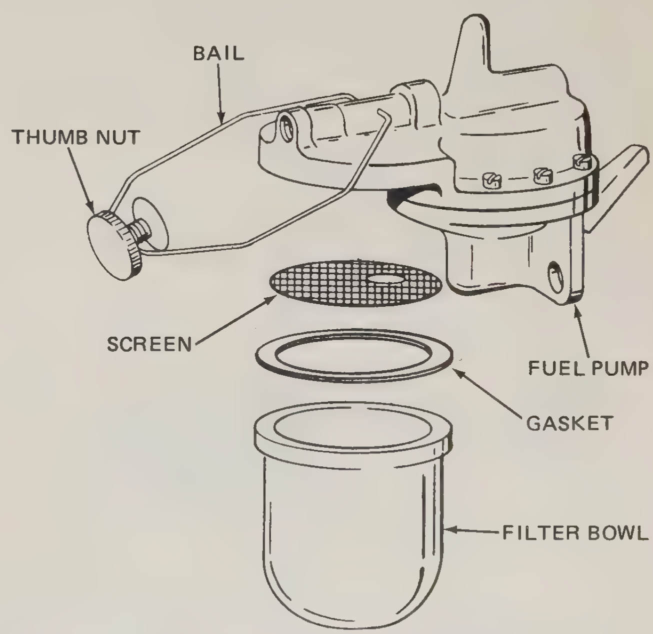


FIG. 18-7 Sediment-bowl type of fuel filter with the filter bowl removed.

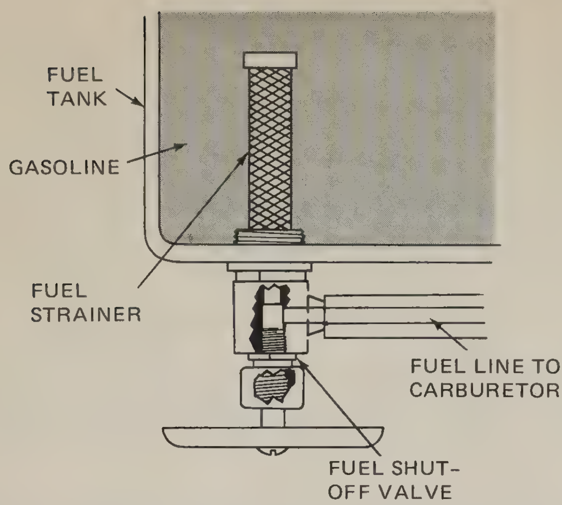


FIG. 18-8 Fuel strainer of type mounted inside the fuel tank.

with a twisting motion. Twisting the bowl reduces the chances of breaking the cork gasket. Remove the gasket and the strainer screen. The screen usually is held in place by the clamping action between the bowl and gasket. On some, the screen is held in place by a retainer clip. Wash the screen and dry it. Wash out the sediment bowl and make sure it is clean. Open the shut-off valve and allow about a cupful of gasoline to drain out into a container. This will remove any dirt in the line between the tank and filter. If the fuel flows out very slowly, the air vent in the fuel-tank cap may be clogged. Remove it to see if the fuel flows more freely. If it does, then clean the cap vents by soaking the cap in solvent.

Install the filter screen, gasket, and sediment bowl. Use a new gasket if needed. If a new gasket is not available, turn the old gasket over upon reinstallation to get a better seal. Before tightening the thumb nut, open the shut-off valve to fill the sediment bowl. This eliminates any air that might otherwise cause an air lock in the line.

The fuel-tank-mounted strainer, shown in Fig. 18-8, may or may not be removable from the fuel tank. If it is, remove it by unscrewing the fuel shut-off valve or tank fitting on which the strainer is mounted. Clean the strainer in solvent, and dry it with compressed air. With the type which is permanently mounted in the fuel tank, remove the fuel tank from the engine. Wash out the tank with solvent several times to clean the tank and strainer.

To clean a weighted strainer, shown in Fig. 18-9, fish the strainer out of the tank with a bent wire. Remove the strainer from the end of the weighted hose. Clean the strainer in solvent. Then dry it with compressed air.

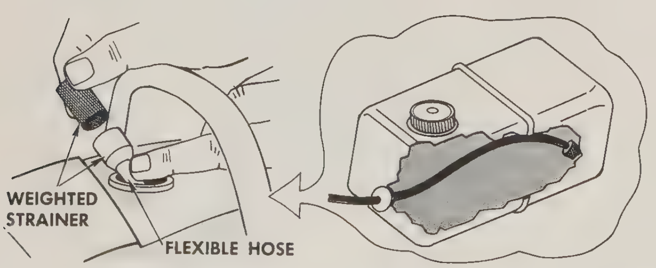


FIG. 18-9 Types of fuel strainer attached to flexible hose inside the fuel tank. (Left) Flexible hose partly pulled from fuel tank so strainer can be removed for cleaning. (Right) Tank partly cut away so hose and strainer can be seen in tank.

○ 18-3 CRANKCASE BREATHER SERVICE

Four-cycle engines must have some way of allowing blow-by gases to escape from the crankcase. *Blow-by* is the seepage of compression and combustion gases from the combustion chamber past the piston and rings. This blow-by can build up pressure in the crankcase if it has no way to escape. Also, blow-by can cause damage to the engine. The blow-by gases can cause corrosion of engine parts and shorten engine life.

Various types of crankcase breathers are used on four-cycle engines to allow the blow-by gases to escape. One type is shown in Fig. 18-10. It consists of a mesh-type filter element and a reed valve. The reed valve is a flexible metal plate which rests against one or more openings in the crankcase. Figure 18-11 shows the reed-valve type of crankcase breather in disassembled view.

When the piston moves down on either the power or intake stroke, pressure is created in the crankcase. This pressure pushes the reed valve open so that the blow-by gases are forced out of the crankcase, as shown to the left in Fig. 18-10. Then, when the piston moves up, either on the exhaust or the compression stroke, a vacuum is produced in the crankcase. This permits atmospheric pressure to push fresh air into the crankcase. Actually, the reed valve is designed so that it will cause a slight vacuum to be retained in the crankcase. This vacuum helps prevent oil leakage through the oil seals and gaskets. To achieve this, the reed valve either has a small hole in it or does not close quite completely. Either arrangement restricts the air entering the crankcase. This causes a slight vacuum to remain at the end of the exhaust or compression stroke.

Leakage through an oil seal on some four-cycle engines is a good indication of a clogged crankcase breather. If the crankcase breather becomes clogged, excessive pressure will build up in the crankcase. This will cause oil leaks and may cause the oil seals to rupture.

Other types of crankcase breathers include a ball-check type and a floating-disk type, shown in Fig. 18-12. These breathers are opened by pressure in the crankcase and partly closed by gravity and by atmospheric pressure.

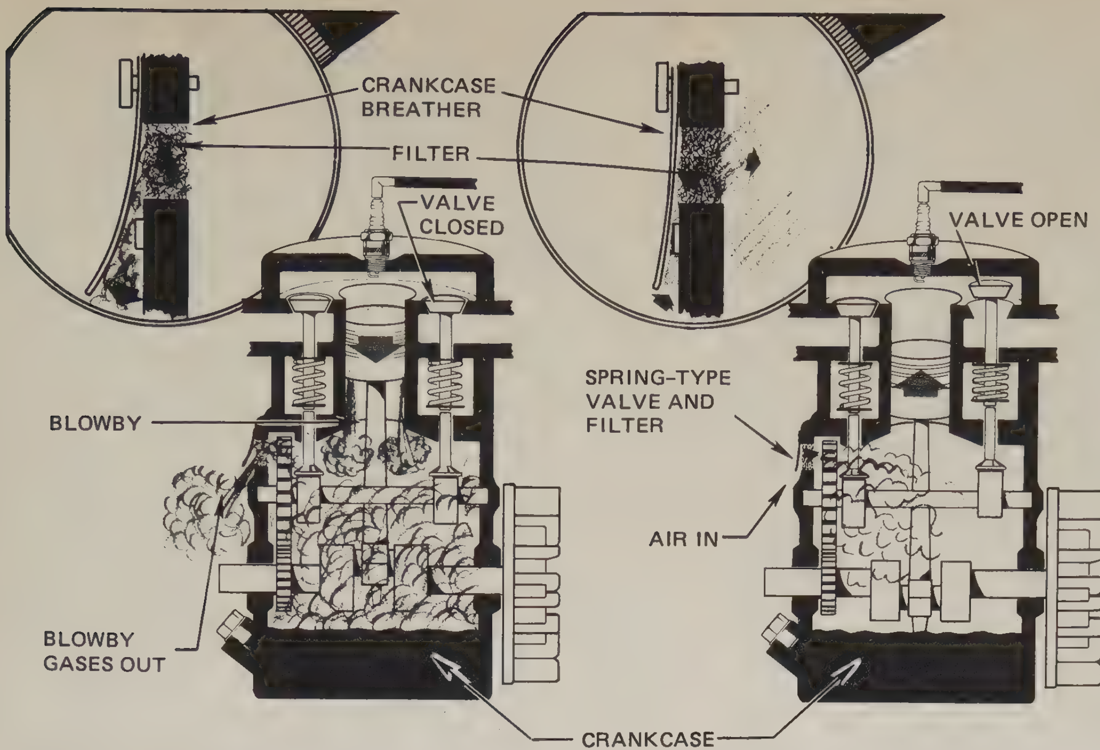


FIG. 18-10 Crankcase breather for a small four-cycle engine. (Left) When the piston is moving down, pressure in the crankcase forces the reed valve to open so blow-by gases are forced out of the crankcase. (Right) When the piston moves up, the partial vacuum created in the crankcase causes the reed valve to close.

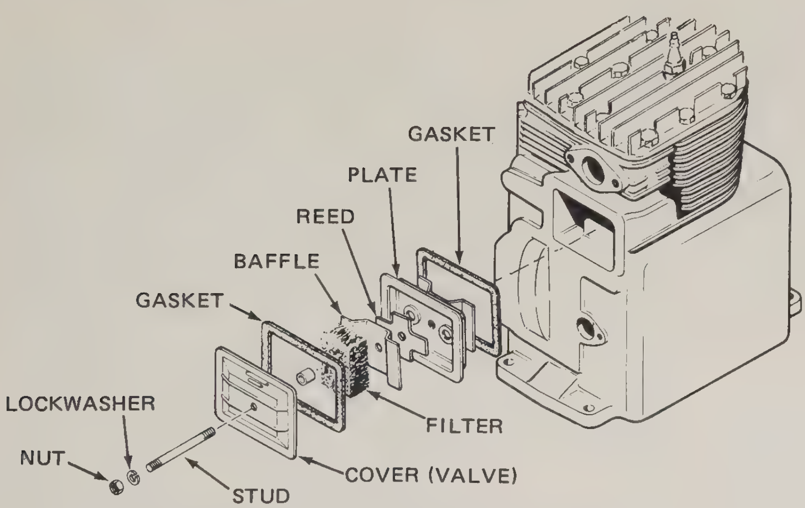


FIG. 18-11 Disassembled view of a crankcase breather for a small four-cycle engine.

The filter element in the floating disk type (Fig. 18-12) is either metal mesh, fiber, or polyurethane. To clean the crankcase-breather filter, remove the nut, screw, or other fasteners which hold it in position. Be sure to note the proper relationships of the various parts as you remove them. Figure 18-11 shows one arrangement. The filter element can be cleaned in solvent and dried. Reassemble the parts in their original positions.

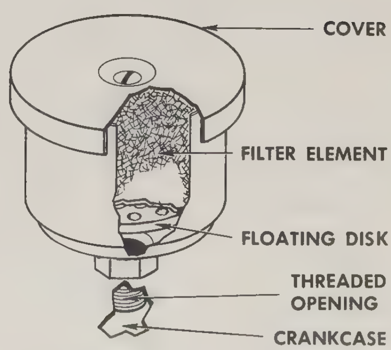


FIG. 18-12 Floating-disk type of crankcase breather for a small four-cycle engine.

Some crankcase breathers have oil-drain holes in them to allow any oil trying to exit from the crankcase to drain back into the crankcase. On these breathers, install the drain hole toward the base of the engine to permit drainage. If the breather is installed upside down, it could cause oil to be pumped out through the breather.

○ 18-4 FUEL-TANK SERVICE Fuel tanks come in a variety of sizes and shapes. Figure 17-2 shows two of the different types. They require very little service. The tanks all have a vent of some sort to admit air when fuel is taken out. Generally, the vent is in the fuel cap. Sometimes the vent will get plugged. This prevents air from entering, and so fuel cannot flow out. The result is that the engine starves for fuel and stops running.

Some fuel tanks have a cap-and-gauge combination. The fuel gauge is made of a float on a twisted blade fastened to the indicating needle. The float moves down as the fuel tank loses fuel. This twists the blade so that the indicating needle moves to indicate the lowered fuel level in the tank.

If the fuel tank is damaged in any way, it should be replaced with a new tank. The tank normally has a bracket which attaches to the engine by screws as shown in Fig. 17-2. Disconnecting the fuel line and removing the screws permits removal of the tank.

○ 18-5 FUEL-PUMP SERVICE Most fuel pumps (Fig. 17-3) are serviced by complete replacement. They are relatively cheap. It may cost more in labor to repair an old pump than to buy a new one. You can check a fuel pump to see if it works by disconnecting the spark-plug wire and the fuel line at the carburetor. Then crank the engine while holding a small container under the fuel line to catch any fuel that appears. If fuel flows out strongly and in regular squirts, the fuel pump is working properly. If fuel flow is weak or erratic, there is something wrong with the fuel pump and it should be replaced.

To remove the old pump, disconnect the fuel lines and take out the screws holding the fuel pump on the engine. Lift the fuel pump off, observing the position of the rocker arm (above or below the eccentric). Install the new pump, making sure the rocker arm goes on the correct side of the eccentric. Then attach the fuel lines and tighten the attaching screws. Figure 17-3 shows the installation of a fuel pump on an engine. The pump lever fits into an eccentric groove on the crankshaft. The part of the lever that rides in the groove should be greased when the pump is installed.

Some manufacturers supply fuel-pump repair information and repair kits. As an example, Fig. 18-13 shows a disassembled fuel pump. Before disassembling this fuel pump, mark the pump cover and pump body with a file as shown in Fig. 18-13. Then on reassembly, you can match the marks and not reverse the cover as it goes on the body.

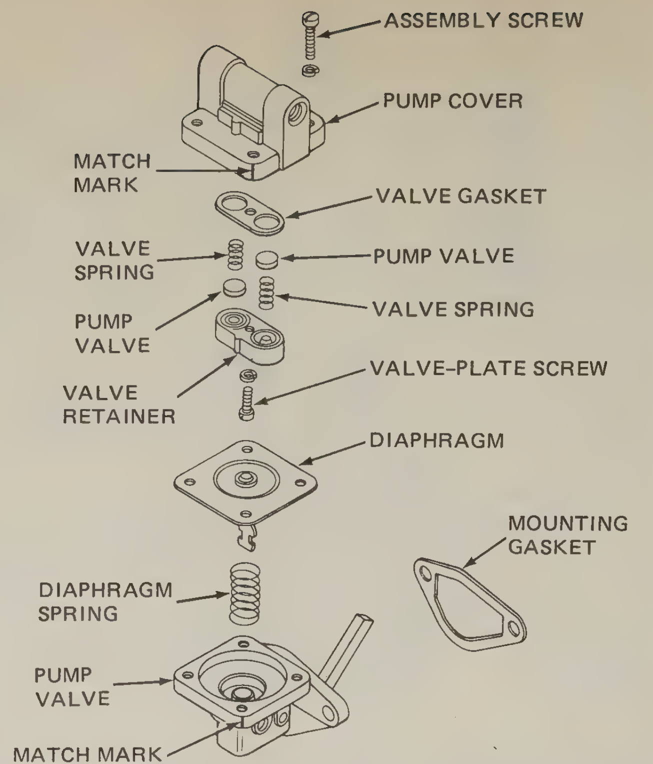


FIG. 18-13 Disassembled view of a fuel pump for a small engine. *(Kohler Company)*

○ 18-6 CARBURETOR SERVICE The carburetor has the job of mixing air and gasoline vapor in the proper ratio to provide good engine operation. If the carburetor is properly adjusted to give this correct air-fuel ratio, it is not likely to go too far out of adjustment in normal operation. However, screws can loosen and throw the adjustment off. In addition, fuel lines and jets in the carburetor can clog. This can mean a partial disassembly of the carburetor for cleaning, which then means a carburetor adjustment. Carburetor servicing is divided into two parts: (1) adjustments and (2) removal and rebuilding.

To adjust the carburetor correctly, there are certain preliminary steps you should take.

1. Fill the fuel tank full except on engines with suction-feed carburetors, which you should fill only half full. Then, when you adjust the suction-feed carburetor, you will be working with an average air-fuel ratio. If you started with a full fuel tank on the suction-feed carburetor, you would adjust correctly for a full tank. Then, as the tank emptied, the mixture would tend to lean out and might become too lean when the tank is nearly empty. With a nearly empty tank, the fuel must be lifted farther. Less fuel would flow into the passing airstream in the carburetor.

2. Be sure the throttle and governor linkages are free and move easily.
3. On four-cycle engines, check the oil level in the crankcase. Add oil, if necessary.
4. Clean the fuel strainer or filter, and the air cleaner, as explained in ○ 18-2.
5. Make sure the fuel-tank cap vent is open. If the vent is clogged, it will prevent normal flow from the tank to the carburetor.
6. Check the ignition and spark plugs.

○ 18-7 CARBURETOR ADJUSTMENTS A great variety of carburetors have been used on small engines. Figure 17-14 is a sectional view of one type. In this and several following sections, we will describe how to adjust carburetors.

Usually, the carburetor has three adjustment screws: one to set the idle speed, one to set the idle mixture, and one to set the high-speed load mixture. These are shown in Fig. 18-16. You may have difficulty deciding which is the idle-mixture adjustment screw and which is the high-speed-load adjustment screw. Two examples are shown in Fig. 18-14. Usually, the idle-mixture adjustment screw is closest to the engine, but this is not always true. If you have any doubts, you can check as follows: Start the engine and operate it at idle speed. Then turn the screw you think might be the idle-mixture screw clockwise, or in toward the closed position. If the engine slows down or stops, you know you have found the idle-mixture screw. If the engine speed changes little or not at all, increase engine speed to about three-fourths throttle. Now, if you get a difference in speed as you turn the screw one way or the other, you have located the high-speed screw.

Many carburetors do not have an idle-mixture adjustment. For these, the idle mixture is preset during manufacture and is determined by the size of the discharge port in the carburetor.

To make the initial adjustments of a carburetor, turn the adjustment screws in until the needles bottom. Then back them off about one turn. This gives an approximate adjustment that should enable you to start the engine and run it until it warms up. Then the final adjustments can be made in accordance with the manufacturer's specifications. We will describe several specific procedures later.

Never tighten the adjusting screws more than finger tight. Excessive tightening can cause the needle to jam down into the seat so tightly that both the needle and seat are damaged.

If adjustment cannot be made to give good engine operation, then either the carburetor should be replaced with a new one or it should be rebuilt. There are carburetor repair kits available which contain all necessary new parts. These kits also include the instructions and specifications for rebuilding the carburetor.

Always install new gaskets when repairing a carburetor. The old gaskets may be hardened and may not provide a good seal. Leakage of fuel or air can occur when old gaskets are reused.

○ 18-8 CHOKE ADJUSTMENT Most chokes in carburetors for small engines are directly controlled by manually operating them. Chokes of this type are shown in Figs. 17-2 (right) and 17-16. Other chokes are controlled by linkage that connects a remote control lever with the choke lever. A typical example of this type of choke control is shown in Fig. 18-15. This type of choke occasionally may get out of adjustment.

To adjust the choke, remove the air cleaner so you can see the action of the choke valve. Move the control lever to the choke position (Fig. 18-15). Now look at the choke valve in the carburetor. The choke valve should be closed. If it is not, adjust the control link-

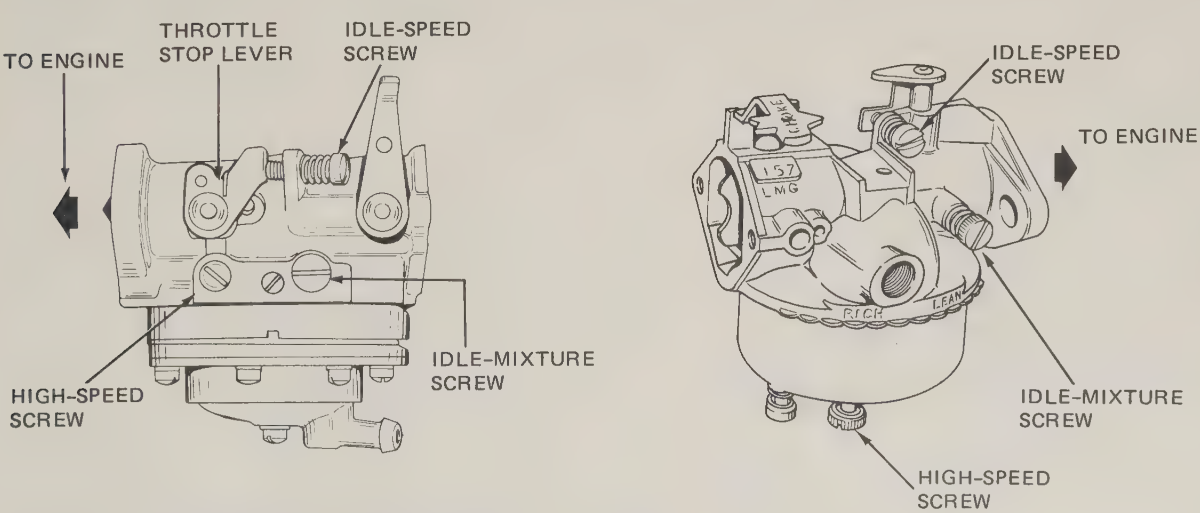


FIG. 18-14 Locations of adjustment screws on two types of small-engine carburetors.

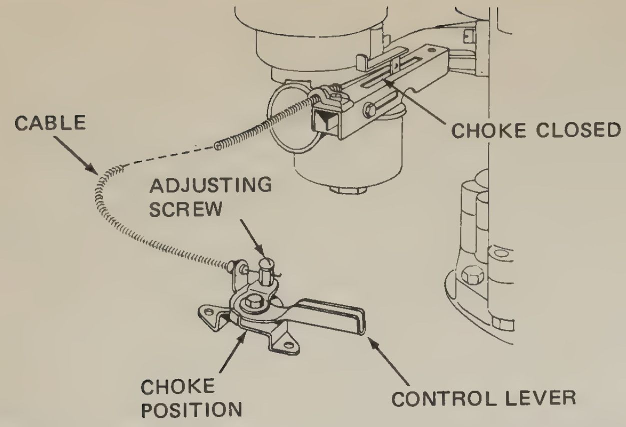


FIG. 18-15 Adjustable, manually operated choke. *(Briggs & Stratton Corporation)*

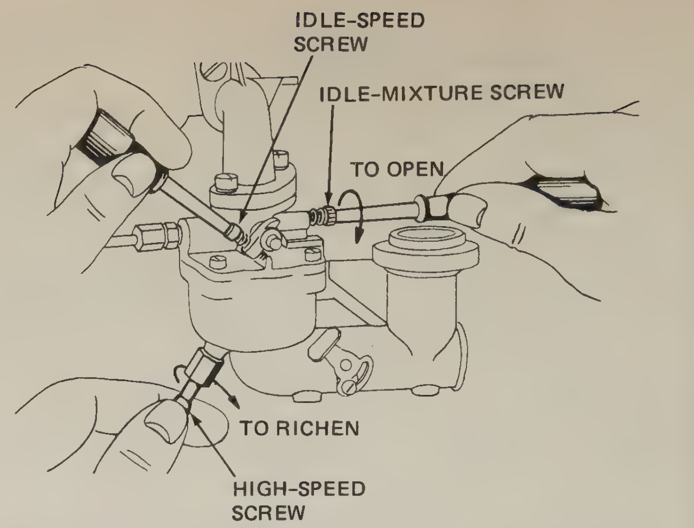


FIG. 18-16 The three adjustment screws on a typical carburetor for a small engine. *(Briggs & Stratton Corporation)*

age or cable. Loosen the adjusting screw and place the control lever in the choke position. Next, check that the choke valve is fully closed. Tighten the adjusting screw. Now move the control lever to the fully open position. Make sure that the choke valve also moves to the fully open position.

Some carburetors have an automatic choke that uses a thermostatic spring or an electric solenoid to control the choke valve. On this type of choke, refer to the engine manufacturer's service manual for the adjustment procedure. The thermostatic-spring type of automatic choke can be checked by noting the choke position with the engine cold (it should be partly to fully closed) and then with the engine hot (it should be wide open). If the choke does not work this way, then the thermostat is faulty or adjustment is required. If the engine uses an electric starter and solenoid, operate the starter and note whether or not the solenoid is actuated. If it is not, then the solenoid is faulty or the starter switch or wiring circuit is defective.

○ 18-9 HIGH-SPEED LOAD ADJUSTMENT The high-speed screw in two different carburetors is shown in Fig. 18-14. The high-speed load adjustment affects the air-fuel mixture ratio when the engine is operating at rated speed and under full load. The engine must be warmed up to normal operating temperature, and the engine should be under full load when this adjustment is made. If you cannot load the engine to make the adjustment, then make the adjustment without load. But after the adjustment be sure to check the engine operation under normal full load. Use an rpm indicator, called a tachometer, to get an accurate reading of engine speed during the adjustment. The operation and use of the tachometer are discussed in later chapters.

With the engine operating at full speed, turn the high-speed screw (shown in Fig. 18-16) in slowly until the engine begins to slow down. When this happens, the air-fuel mixture has leaned out so much that the engine power is reduced. Now slowly turn the adjustment screw out until the engine slows down or the exhaust begins to turn black. At this position, the needle is passing too much gasoline and so the mixture is too rich. Not all the gasoline burns, and this turns the exhaust black. Next, slowly turn the adjustment screw in until the engine runs smoothly and at full speed.

Make adjustments of about one-eighth turn at a time. Then wait a few seconds between turns for the engine to adjust to the changed air-fuel mixture.

○ 18-10 IDLE-MIXTURE ADJUSTMENT This adjustment affects the mixture richness when the engine is idling. Many carburetors do not have this adjustment, because the idle-mixture port is usually fixed. If the carburetor does have the adjustment as shown in Fig. 18-16, it is made with the engine running and warmed up. First, turn the idle-speed screw, with the engine idling, to get the lowest engine speed possible without stalling. Next, turn the idle-mixture screw in until the engine begins to slow down or roll. This means that the mixture is too lean to support normal engine operation. Now turn the idle mixture screw back out slowly until the engine idles smoothly. Recheck the high-speed load adjustment to make sure it is still correct. Then operate the throttle several times from idle to full speed to make sure the engine will go from idle to full speed and back again without hesitation. Finally, adjust the idle speed as explained in the following section.

○ 18-11 IDLE-SPEED ADJUSTMENT This adjustment shown in Fig. 18-16 is controlled by a stop screw which can be turned in or out to charge the idle speed. Its basic purpose is to prevent the throttle

valve from closing completely and causing the engine to stall. Small engines usually idle at fairly high speeds, from 1200 to 3000 rpm. Always check the manufacturer's service manual to determine the specified speed before attempting to set the idle speed. Most specifications call for setting the idle speed at about one-half full speed. If the engine is idled too slowly, spark plugs, pistons, and exhaust ports on two-cycle engines will soon foul up from carbon, due to only partly burned gasoline.

Idle speed should be set with the engine warmed up. Therefore, the other settings discussed above should be made first. Then a tachometer should be used to measure the speed while the idle-speed screw is turned to obtain the specified speed.

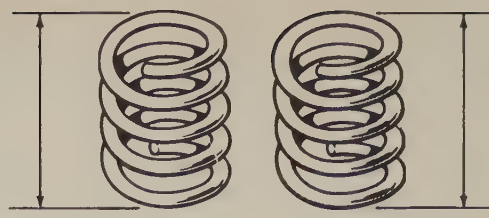


FIG. 18-18 On some engines, the governor spring must be changed to change governed engine speed. *(Lawn Boy Division of Outboard Marine Corporation)*

○ 18-12 FLOAT ADJUSTMENT The float should be adjusted so that the proper level of gasoline will be maintained in the float bowl. Normally, this adjustment will not change. However, if the carburetor requires repair, then this adjustment should be checked. The procedure of checking the float level on one model of carburetor is shown in Fig. 18-17. The float should be parallel to the body mounting surface with the body gasket in place and the needle valve and float installed. Bend the tang on the float, if necessary, to bring the float to parallel.

○ 18-13 GOVERNOR SERVICE There are two general types of governors: the air-vane type and the centrifugal type. The air-vane type works on a blast of air from the blades on the engine flywheel. The centrifugal type is operated by a centrifugal device which is actuated by engine speed.

If the engine is not governed at the correct speed, the governor should be adjusted. On some engines, this can be done by bending the link between the throttle and the governor or making some similar linkage adjustment. On others, the spring can be changed to change the engine speed. An example is shown in Fig. 18-18. Do not attempt to adjust the governor speed by stretching a spring. This will not work, because you may weaken the spring and it will probably go back to its original set after a while.

Figure 18-19 shows various methods of adjusting governors of different designs. One of the most important things to remember when adjusting a governor is not to increase engine speed above its specified maximum rpm. Excessive engine speed greatly shortens engine life. If you cannot find the design of governor linkage you are working on in Fig. 18-19, refer to the service manual covering the engine on which the governor is mounted.

From the standpoint of governor service, you will find three basic types: the air-vane type, the externally mounted centrifugal type, and the internally mounted centrifugal type.

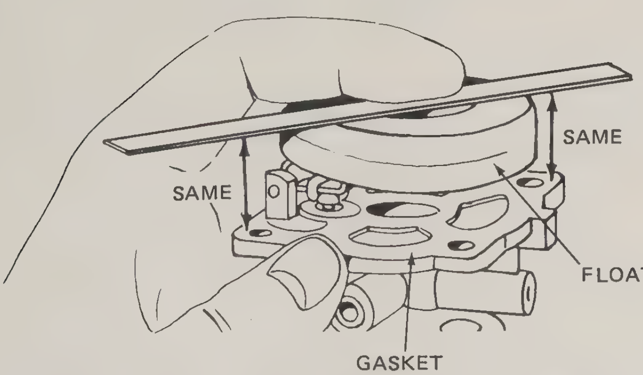


FIG. 18-17 Checking the float level on one model carburetor. *(Briggs & Stratton Corporation)*

Air-Vane Governor Figure 18-20 shows an air-vane governor. There is little in the way of service this governor requires. To gain access to the governor, remove the engine shroud. Make sure the air vane is not bent and that it is free to move when air blows on it.

Externally Mounted Centrifugal Governor Servicing this type of governor, mounted under the flywheel, as shown in the upper left in Fig. 18-19, requires removal of the flywheel. If you must take the governor apart, be sure to notice how the parts fit together so that you will have no trouble reinstalling the governor.

Internally Mounted Centrifugal Governor If the governor is mounted inside the engine crankcase, as shown in Fig. 18-21, disassemble the engine to gain access to the governor. These governors sometimes are more complicated in design. Be especially careful to note the relationship of all parts before disassembling the governor.

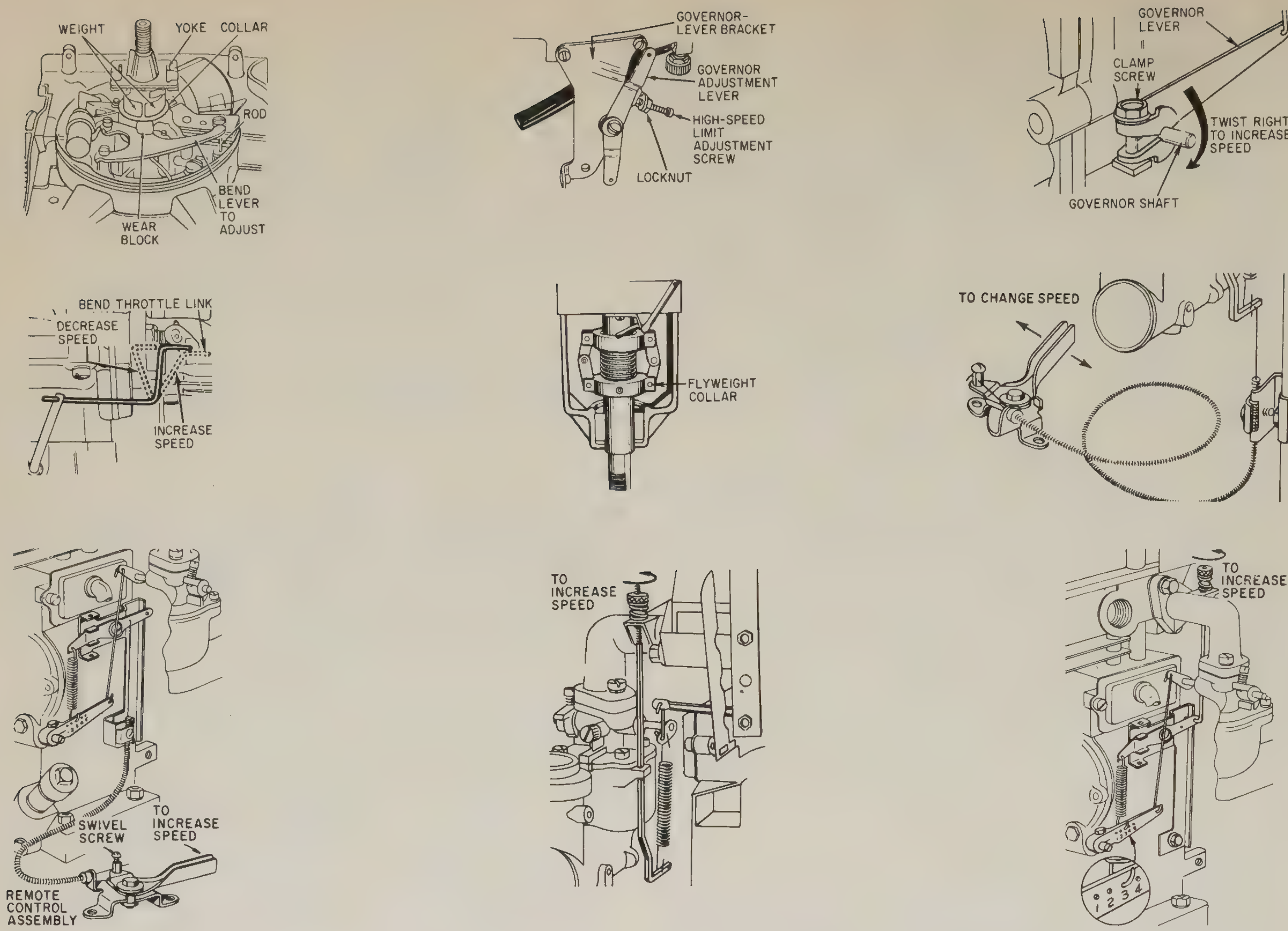


FIG. 18-19 Methods of adjusting governor on different engines. The nine methods shown here include most adjustment methods.

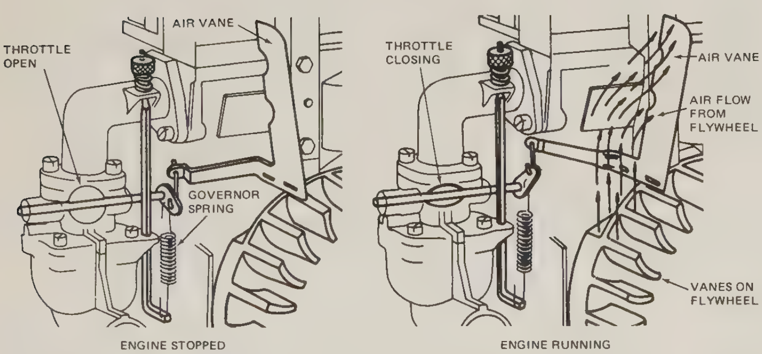


FIG. 18-20 Operation of an air-vane governor. *(Briggs & Stratton Corporation)*

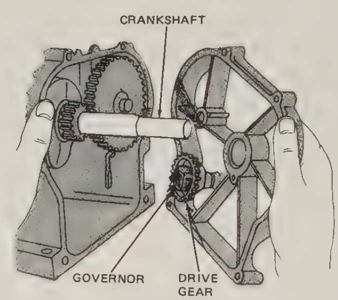


FIG. 18-21 Location of an internally mounted governor on one engine.

REVIEW QUESTIONS

1. What, in the fuel system, could cause failure to start when the engine cranks normally?
2. If the trouble is overchoking so the engine is flooded, what can you do to start the engine?
3. Why should you not crank the engine with the air cleaner off?
4. What can cause excessive fuel consumption?
5. How do you tell that the air-fuel mixture is too rich?
6. Name four cautions to observe in fuel-system work.
7. Explain how to clean the paper filter element.
8. How often should you clean the oil-bath air cleaner?
9. Which is the more common method of servicing defective fuel pumps: by disassembly and repair or by replacement?
10. What are the three carburetor adjustments?
11. Describe a typical idle-speed adjustment.
12. Describe how to make the high-speed load adjustment.

SELF PROJECT

There are instruction sheets in carburetor overhaul kits. These kits tell you, step by step, how to overhaul the carburetors for which the kits were designed. They have pictures showing the various steps in the procedure. You should be able to get several of these from local shops that handle carburetor work. Also, your school shop may have copies of these instruction sheets. Study the instruction sheets. Make a collection of them if you can. Tape them to sheets of paper and file them in your notebook.

19 Chapter

Engine Cooling Systems

After studying this chapter, you should be able to:

1. **Describe the purpose of the engine cooling system**
2. **List the types of cooling systems and describe the operation of each**
3. **Explain how to service the cooling system on an air-cooled engine**
4. **Explain how the water pump and thermostat work in a liquid-cooling system**
5. **Explain the purpose of pressurizing the liquid-cooling system and how it is done**

○ 19-1 PURPOSE OF COOLING SYSTEM In this part of the chapter we discuss the construction and operation of engine cooling systems. The cooling system is an integral part of the engine, and the operation of one depends on the operation of the other. The cooling system will not operate unless the engine is running. The engine will not operate for very long if the cooling system is inoperative.

The purpose of the cooling system is to keep the engine at its most efficient operating temperature at all engine speeds and under all operating conditions. During the combustion of the air-fuel mixture in the engine cylinders, temperatures as high as 6000°F [3316°C] may be reached by the burning gases. Some of this heat is absorbed by the cylinder walls, cylinder head, and pistons. They, in turn, must be provided with some means of cooling so that their temperatures will not reach excessive values that melt them. Cylinder-wall temperature must not increase beyond about 400 to 500°F [204 to 260°C]. Temperatures higher than this will cause the lubricating-oil film to break down and lose its lubricating properties. However, it is desirable to operate the engine at temperatures as close to the limits imposed by oil properties as possible. Removing too much heat through the cylinder walls and head would lower engine thermal efficiency. Cooling systems are designed to remove 30 to 35 percent of the heat produced in the combustion chambers by the burning of the air-fuel mixture.

Two general types of cooling systems are used: air-cooling and liquid-cooling. Most automotive engines employ liquid cooling. Most small engines for power equipment such as lawn mowers, motorcycles, and other similar applications are air-cooled.

○ 19-2 AIR-COOLED ENGINES Almost all small single-cylinder engines, both two-cycle and four-cycle, are air-cooled. No radiator, water jackets, water pump, or liquid coolant is used. This means

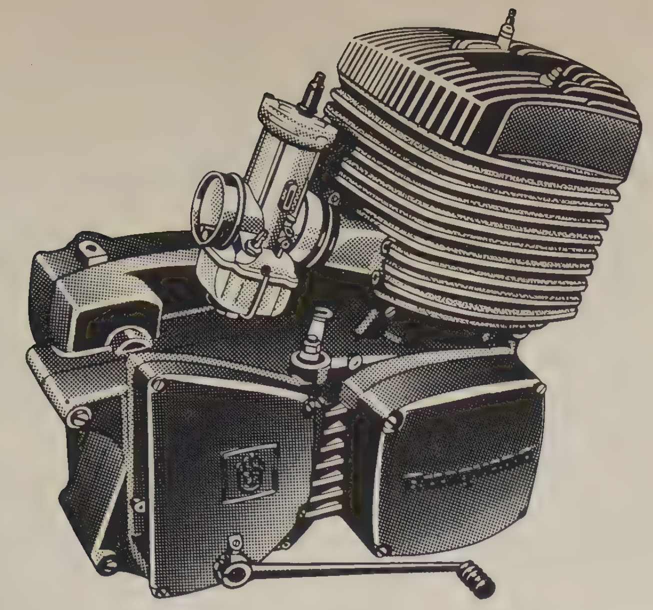


FIG. 19-1 Open, or open-draft, type of air-cooling system used on most motorcycle engines. *(Husqvarna)*

that the air-cooled engine is very economical to manufacture and easier to maintain. Instead of the relatively complicated liquid-cooling system, the cylinder simply has fins all around to cool it, as shown in Fig. 19-1. These fins are actually part of the head and cylinder. They greatly increase the outer metal surface area of the engine from which heat can escape into the surrounding air.

There are two types of air-cooling systems. The simpler is the open, or open-draft, system, used on most motorcycle engines. This system is shown in Fig. 19-1. The second type of air-cooling is the forced-draft system, used on most other small engines. This system is shown in Fig. 19-2. We will discuss these two systems in detail later.

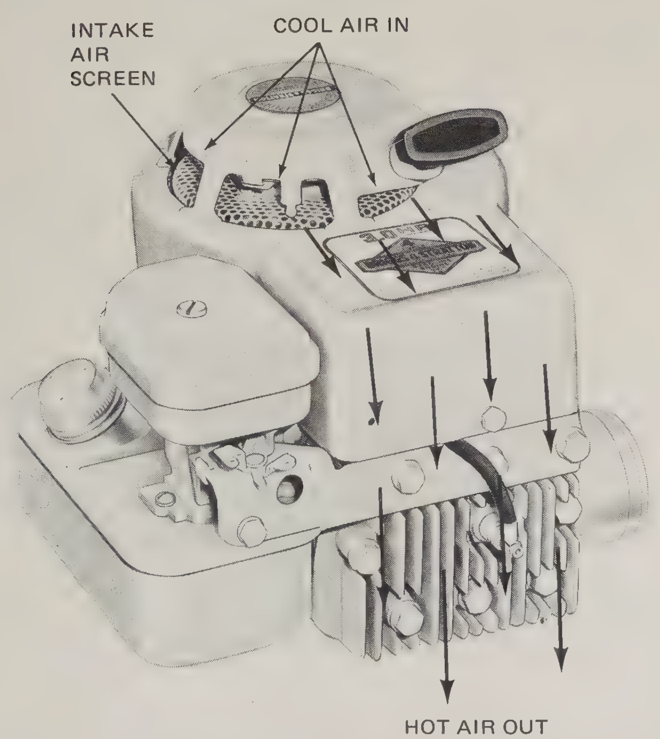


FIG. 19-2 Forced-draft type of air-cooling system used on most small engines. *(Briggs & Stratton Corporation)*

The purpose of any engine cooling system is to remove excess heat from the engine to prevent the engine from overheating and damaging itself. To better understand cooling systems and how they work, let us briefly review a few important facts about heat.

○ 19-3 HEAT If someone asked you to define *heat,* you might say that it is something that keeps a person warm, that raises the temperature, or that makes water boil or iron melt. Heat produces all these effects. But scientists look at heat in a different way. They say that heat is simply an indication of the rapid motion of the atoms and molecules of a substance.

Heat is a form of energy. As a form of energy, heat has the ability to do work. It is released by the burning of any fuel. In an engine, heat energy is converted to mechanical energy. But in the combustion process, more heat is created by the burning fuel than is converted into mechanical energy. It is the necessity to remove this unused or excess heat that requires engines to have a cooling system. We will discuss this further later. Let us meanwhile continue talking about heat and some of its more important characteristics.

Temperature is the name given to the measurement of heat intensity, or how hot something is. If we touch an object that is warmer than our body temperature, we usually say the object is hot. When the temperature of the object is cooler than our body temperature, we say the object is cold. When an engine is at room

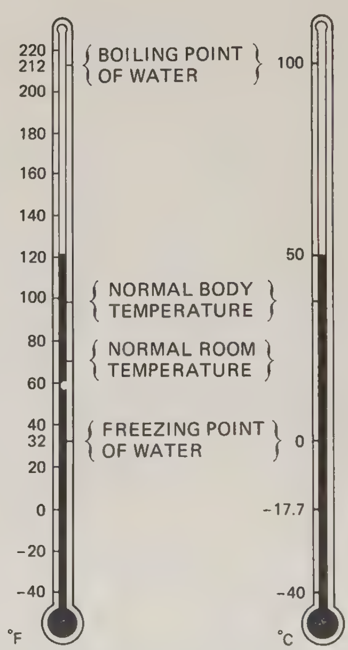


FIG. 19-3 Thermometers comparing Fahrenheit and Celsius (also called centigrade) readings.

temperature or has not run for at least several hours, we say the engine is cold. If the engine has run recently, perhaps within the last two hours, we say the engine is warm, or warmed up.

We state the temperature of an object as so many degrees and read it on a thermometer or temperature gauge such as those shown in Fig. 19-3. In this country, in past years temperature was measured on the Fahrenheit scale, which has water freezing at 32°F and boiling at 212°F. Now, with the metric system coming into use, temperature measurements are made using the Celsius scale, formerly called the centigrade scale. On the Celsius scale, water freezes at 0°C and boils at 100°C.

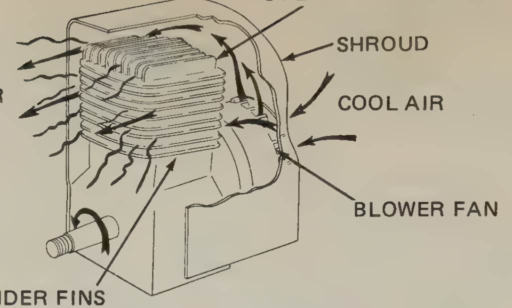


FIG. 19-5 Circulation of air around the fins of an air-cooled engine. This is an example of heat transfer by convection.

○ 19-4 AIR-COOLING THE ENGINE

The job of the cooling system is to remove excess heat from the engine. To do this, heat must travel from the burning combustion gases through the cylinder to the fins. The movement of heat from one place to another is called *heat transfer*.

There are three ways that heat can travel from one place to another. These three methods of heat transfer are conduction, convection, and radiation. Now let us take a brief look at each of these.

Conduction is the transfer of heat through a solid object. Here is a simple experiment that demonstrates conduction: Hold one end of a small metal rod in a flame. In only a few seconds the cooler end you are holding begins to get hot. This is because the closely packed molecules in the rod are set in rapid motion by the flame. Heat travels through the solid rod from molecule to molecule by conduction. Exactly the same thing happens in the air-cooled engine. Heat travels, by conduction, from the cylinder walls through the cylinder to the cooling fins, as shown in Fig. 19-4.

Liquids and gas do not conduct heat very well. For example, air is a gas which is a very poor conductor of heat. However, both air and liquid are used to provide the second method of cooling that we will discuss: convection cooling.

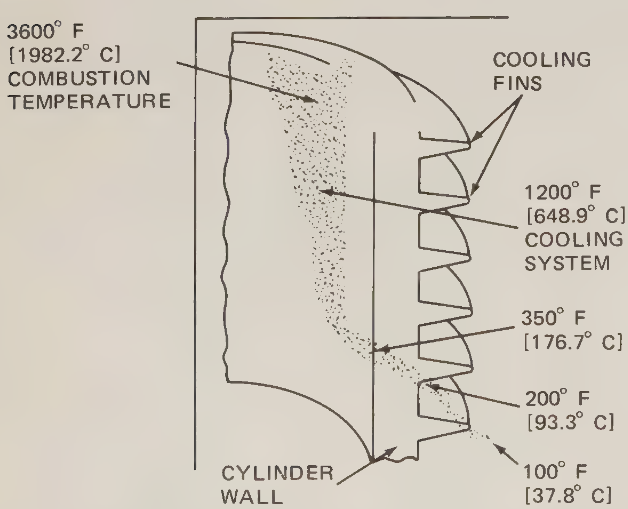


FIG. 19-4 Heat-travel path from combustion gases to the lower cooling fins. This is an example of heat transfer by conduction.

There is a difference between conduction and convection. In conduction, heat passes through a solid object that does not move. In convection cooling, a liquid or gas moves from one place to another, carrying the heat with it. This is the basis for the design of engine cooling systems. Hot air or hot liquid rises. Cooler air or liquid moves in to take its place.

Earlier we mentioned that there are two types of air-cooling systems: the open-draft system, shown in Fig. 19-1, and the forced-draft system, shown in Figs. 19-2 and 19-5. Both of these types are methods of convection cooling. When the air rises from the fins simply because the air gets hot, the system is known as an open-draft or natural-convection system. When a fan is used to force cool air over the hot fins, as shown in Figs. 19-2 and 19-5, this is the forced-draft or forced-convection system.

○ 19-5 LIQUID COOLING

In the automobile engine, a water pump forces the liquid coolant through the engine water jackets as shown in Fig. 19-6. There the coolant picks up heat and carries it to the radiator. The automobile radiator cools by convection, not by radiation. Air pulled through the radiator by the engine fan at low speed, and pushed through at higher speed, picks up heat from the radiator. The passing airstream carries the heat outside the engine compartment. This is another example of cooling by convection. Convection is cooling by moving the air or liquid carrying the heat from one place to another. We will discuss liquid-cooling systems in detail later.

○ 19-6 RADIATION

A third method of heat transfer is called radiation. Perhaps the radiation of heat can best be described as the heat you feel from sunlight or from hot coals in a fireplace across the room. Radiation provides no significant amount of heat transfer from either air-cooled or liquid-cooled engines, so we will discuss it no further.

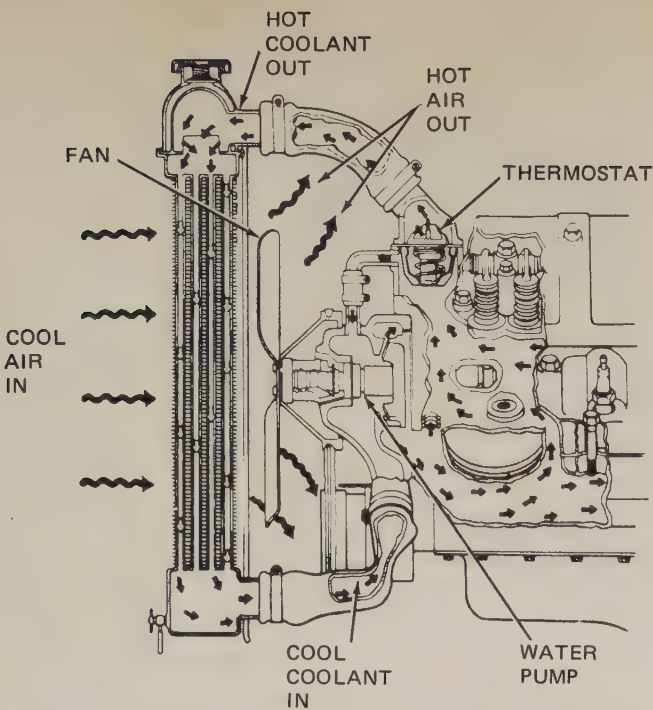


FIG. 19-6 Automobile engine cooling system. Wavy arrows show path of air, solid arrows show path of liquid coolant. This is an example of heat transfer by convection.

○ 19-7 AIR-COOLED ENGINE CONSTRUCTION In an air-cooled engine, each cylinder is semi-independent, with its own cooling system of fins all around to cool it. A typical one-cylinder air-cooled engine is shown in Fig. 19-2. The fins are actually part of the head and cylinder. Their purpose is to greatly increase the outside metal surfaces of these parts. This, in turn, greatly increases the area from which heat can escape into the surrounding air.

To assist in this heat escape, many engines have shrouds and a cooling fan, which some manufacturers call a *blower*. The cooling fan is usually part of the flywheel, as shown in Figs. 19-5 and 19-7. Shrouds are metal sheets shaped to fit around the cylinder in such a way that they force the air from the fan to flow between the fins. Shrouds are held in place by screws, which can be taken out so the shroud parts can be lifted off.

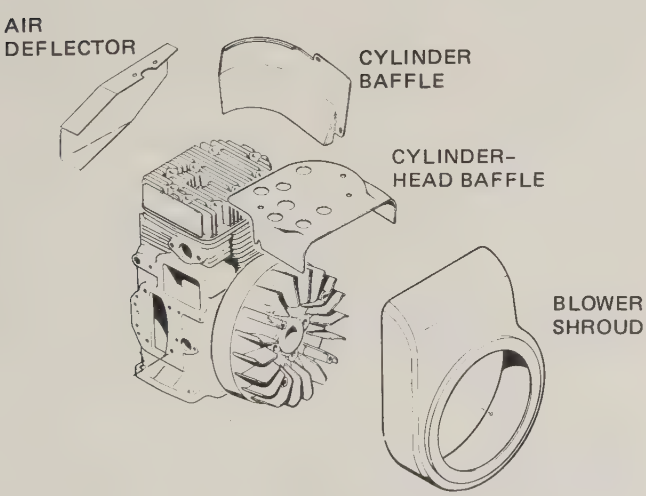


FIG. 19-7 Small engine with the shrouds removed.

○ 19-8 ARRANGEMENTS OF FINS Various arrangements of the cooling fins have been used. The fins are always so placed that the cooling air passes between them. As you look at the pictures in the book and examine actual air-cooled engines, note the size and arrangement of the fins. With open-draft engines, such as used on motorcycles, the fins are usually rather long (Fig. 19-1). They are arranged so that the forward motion of the motorcycle will allow air to flow between them. Also in engines using forced draft that have a fan or blower, fins are arranged so the draft of air flows between them (Fig. 19-5).

○ 19-9 SERVICING AIR-COOLED-ENGINE COOLING SYSTEMS The engine does not always get the maintenance it should, with the result that its life is shortened. One of the most important services is to clean the engine and its engine components such as the shroud, intake-air screen, fan, and most important, the fins. It is dirt, more than anything else, that is the enemy of long engine life.

Fins on the head and cylinder provide large surface areas from which heat can be dissipated. The heat flows from the inside of the cylinder, through the cylinder metal, to the fins, which transfer it to the outside air, as shown in Fig. 19-4. If these fins become dirty or covered with oil or grass clippings, the heat cannot get through. The accumulations act as a blanket to hold heat in the engine. As a result, the engine becomes overheated. The oil film on the engine parts becomes less effective or actually fails. The result is that engine parts wear rapidly and engine life is shortened. Therefore, it is essential for long engine life to clean the engine before each use if doing so is required.

Another purpose of periodically cleaning the engine is to check for loose nuts or bolts and loose, broken, cracked, or otherwise damaged parts. One way to clean the engine is to use a stiff brush and water. A wet brush will get into all the crevices where dirt can accumulate and clean away most of the grass clippings and other trash that can cause trouble. For a complete cleaning job, use a degreasing compound as explained later.

CAUTION: Do not clean a hot engine. Wait until it is cool. If you throw water on a hot engine, you can crack the cylinder. Also, many degreasing compounds are flammable: they could burst into flames when sprayed on a hot engine.

○ 19-10 SERVICING COOLING SYSTEM PARTS

Cooling system parts to be cleaned include the shrouds, fan, and fins. Many small engines have fans and shrouds to direct the flow of air around the engine cylinder as shown in Fig. 19-2. The shroud will have to be removed before the engine can be cleaned. Figure 19-7 shows one shroud arrangement. Shrouds are held in place by screws. These screws can be taken out to allow the shroud parts to be lifted off.

On a few engines it will be necessary to remove certain other parts before the shroud can be removed. These parts might include the air cleaner, muffler, spark-plug wire, governor spring, or some other minor part.

Never operate the engine with the shroud and baffles removed! The shroud is there to force cooling air over the engine. When the shroud is off, the engine will overheat if operated. In addition, engines which have air-vane governors that operate on air flow will not function properly with the shroud off. The possible result is that the engine can overspeed and probably ruin itself.

If the shroud is bent or damaged, it should be straightened repaired, or replaced. A defective shroud can cause engine overheating. A defective shroud also might interfere with the fan or other moving parts.

If the shroud is dirty and has accumulations of grass clippings or other trash, scrape it clean with a putty knife or similar tool. Use a stiff-bristled brush and solvent if needed. Clean the air-intake screen with a brush and solvent, if necessary, to get rid of all accumulations of trash that could prevent normal air flow through it.

The fins on the cylinder and cylinder head should be clean to permit maximum heat transfer from the engine to the surrounding air. Three substances for cleaning the cylinder and head can be used: a degreaser, a solvent, and live steam. As a first step, use a wooden stick to scrape away all the accumulated trash, dirt, and grease. Do not use a metal tool, because this will scratch the cylinder and head and encourage accumulations of dirt. Then use the material you have on hand to finish the cleaning job. Degreasing compound comes in pressure spray cans or in larger containers. To use live steam, you need a steam cleaner. This is available in many shops.

While cleaning the cylinder and head, check for oil leaks, which usually show up as a heavy accumulation of dirt. Check also for cracks or other damage. Then apply the cleaning agent on the areas to be cleaned. The degreaser in the pressure can is the easiest to use. Other types of solvent can be applied with a bristle brush. After about five minutes, flush off the solution with a stream of water from a hose. If you have used solvent, use a solution of soapy water brushed on and then flushed off.

CAUTION: Do not clean a hot engine. Allow it to cool first. Cold water or other liquid on the hot engine can cause the head or cylinder to crack. Some cleaning solutions are flammable; they could burst into flames if sprayed on a hot engine. Also, make sure that there is adequate ventilation. Some fumes from cleaning solutions are unhealthy to breathe.

○ 19-11 LIQUID-COOLING SYSTEMS

There are two methods of cooling an engine: One method, which we have just studied, is air cooling. The second method is liquid, or water, cooling. Most multicylinder engines, particularly those used in automobiles and some motorcycles, and some small engines are of the liquid-cooled type.

In liquid-cooled engines, a liquid is circulated around the cylinders and head, through passages called water jackets, to absorb excess heat from the cylinder and combustion chamber walls. The liquid is water mixed with an antifreeze solution, which is usually the chemical ethylene glycol. This mixture is called *coolant*. The antifreeze lowers the freeze point of the liquid mixture, raises the boiling point, and helps prevent corrosion of the metal water-jacket surfaces. A widely used mixture for coolant is half water and half antifreeze.

As the coolant circulates, it picks up heat from the engine and carries this heat to the radiator. The radiator then cools the coolant by the process of convection. The radiator transfers the heat from its fins to the air passing between them. The coolant, water jackets, radiator size, and other details of the cooling system are designed so as to maintain the cylinder walls, head, pistons, and other working parts at efficient, but not excessive, temperature. Two types of liquid-cooling systems are used. These are the natural-circulation, or thermosiphon, system and the forced-circulation system.

○ 19-12 THERMOSIPHON COOLING

Thermosiphon, or natural-circulation, cooling is not a widely used system. However, you may find some engines that are cooled by this type of system. Thermosiphon cooling depends upon the expansion of heated coolant for the motive power that causes the coolant to circulate.

Figure 19-8 shows the basic thermosiphon-cooling system. The coolant around the cylinders is heated. Consequently, the coolant expands so that the weight of a given volume is decreased. Since the heated coolant is lighter, it rises and is displaced by the cooler and heavier coolant from the radiator. The heated coolant enters the top of the radiator and begins to lose heat to the air passing through the radiator. As the coolant cools, it contracts and becomes heavier. It then sinks to the bottom of the radiator, continuing to lose heat as it does so.

FIG. 19-8 Simplified diagram of the thermosiphon type of liquid-cooling system. (A) Cylinders, (B) water jackets, (C) return hose, (D) upper hose, (E) radiator, and (F) upper tank.

The pressure that it exerts through the return line to the cylinders causes the warmer coolant around the cylinders to rise. This provides constant circulation of the liquid between the cylinders and the radiator. The hotter the engine, the more rapidly the coolant circulates. The system tends to maintain fairly constant cylinder-wall temperatures.

The disadvantage of thermosiphon cooling is that circulation is seriously reduced by an accumulation of scale or foreign matter in the passages and lines. This, in turn, causes overheating of the engine.

○ 19-13 FORCED CIRCULATION In the forced-circulation system, a water pump is used to assure continued and rapid circulation of the cooling liquid. Figure 19-9 shows a cooling system on a four-cylinder pancake engine. The water pump, driven by the engine, keeps the coolant in continuous circulation while the engine is running. Figure 19-9 shows where the water pump is mounted on this engine. The coolant enters the water pump from the bottom of the radiator, where it is pressurized and forced up through spaces in the cylinders and heads. These spaces are called *water jackets*. In Fig. 19-10 the arrows point to the water jackets, or coolant passages, in the cylinder block and head of an engine. Figure 19-11 shows the water jackets in a single cylinder of a four-cycle engine.

○ 19-14 WATER PUMP Water pumps are of the impeller type. They are mounted at the front end of the engine between it and the radiator. See Figs. 19-6 and 19-9. A disassembled water pump is shown in Fig. 19-12. The pump consists of a housing, with a coolant inlet and outlet, and an impeller. The impeller is a flat plate mounted on the pump shaft with a series of flat or curved blades, or valves. When the impeller rotates, the coolant between the blades is thrown outward by centrifugal force and is forced through the pump outlet and into the cylinder block. The pump inlet is connected by a hose to the bottom of the radiator. Coolant from the radiator is drawn

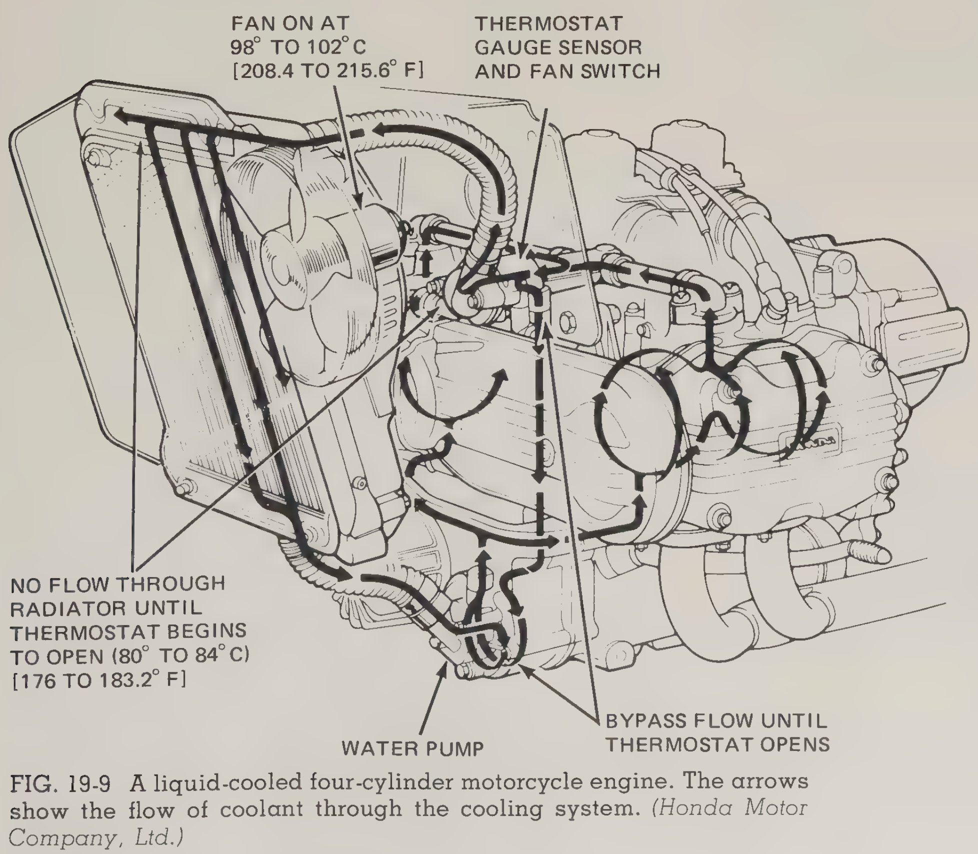


FIG. 19-9 A liquid-cooled four-cylinder motorcycle engine. The arrows show the flow of coolant through the cooling system. *(Honda Motor Company, Ltd.)*

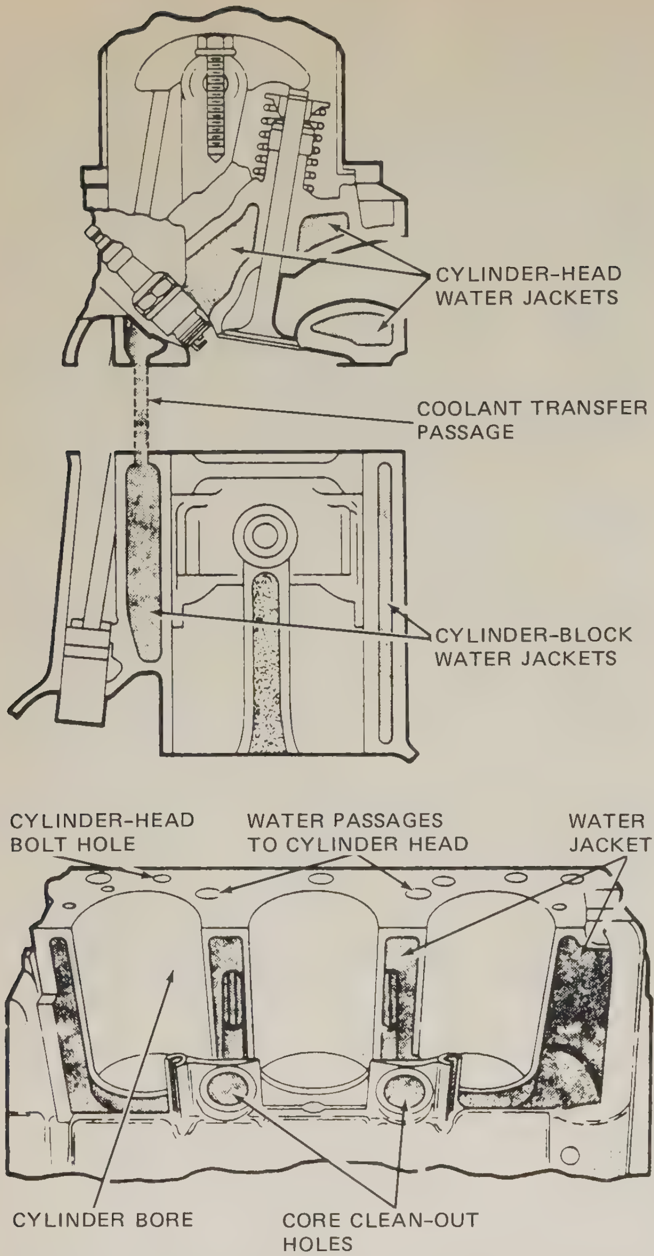


FIG. 19-10 Water jackets, or coolant passages in a cylinder block and head.

into the pump to replace the coolant forced through the outlet.

The impeller shaft is supported on one or more bearings. A seal prevents coolant from leaking out around the bearing. The type of water pump shown in Fig. 19-12 is driven by a belt to the drive pulley, which is attached to the front end of the engine crankshaft. The water pump on the engine shown in Fig. 19-9 is mounted on the same shaft as the engine oil pump and is driven by an enclosed chain.

○ 19-15 ENGINE FAN On some engines the engine fan mounts on the water-pump shaft and is driven by the same belt that drives the water pump. This is shown in Fig. 19-6. The purpose of the fan is to

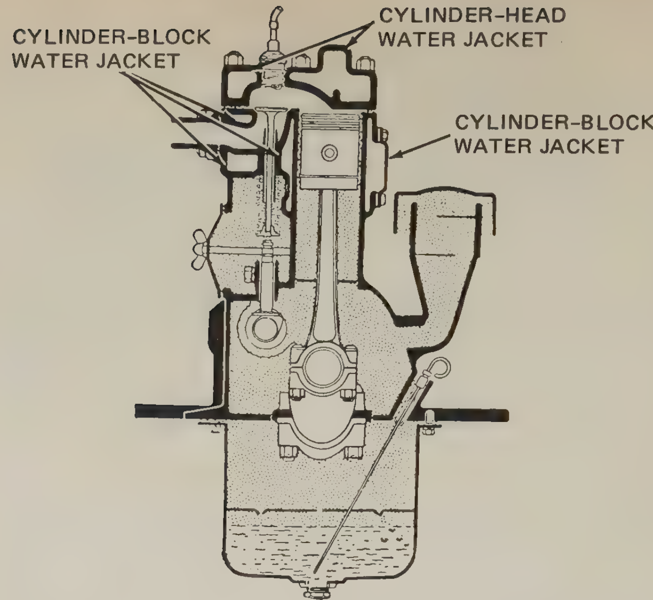


FIG. 19-11 Water jackets in the head and cylinder block of a four-cycle engine.

provide a flow of air through the radiator to improve engine cooling. The fan usually has from two to six blades which, in rotating, pull air through the radiator. Some engines are equipped with a fan shroud that improves fan performance. The shroud increases the efficiency of the fan, since it assures that all air pulled back by the fan must first pass through the radiator.

○ 19-16 RADIATOR The radiator holds a large volume of coolant in close contact with a large volume of air so that heat will transfer from the coolant to the air. The radiator core is divided into two separate and intricate compartments. Coolant passes through one, and air passes through the other. The actions in one type of radiator are shown in Fig. 19-13. There are several types of radiator construction. The tube-and-fin type of radiator shown in Fig. 19-13 consists of a series of tubes extending from the top to the bottom of the radiator, or from the upper to the lower tank. Fins are placed around the tubes to improve heat transfer. Air passes around the outside of the tubes, between the fins, absorbing heat from the coolant in passing.

Some liquid-cooling systems have a separate expansion tank, or reserve tank, as shown in Fig. 19-14. The expansion tank is partly filled with coolant and is connected to the radiator filler neck. The coolant in the engine expands as the engine heats up. This sends some of the coolant into the expansion tank instead of leaking it out on the ground. When the engine approaches operating temperature, a valve in the radiator cap closes, sealing the cooling system. The pressure in the cooling system increases and prevents boiling. This allows the cooling system to operate at a higher temperature so it is more efficient.

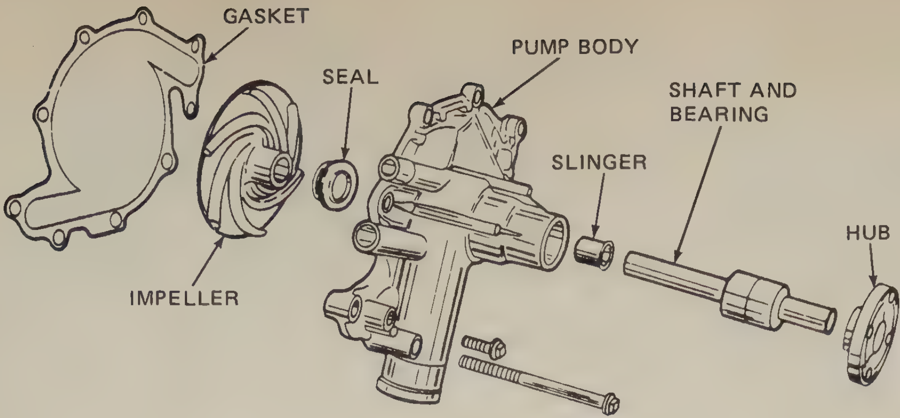


FIG. 19-12 Disassembled view of a water pump.

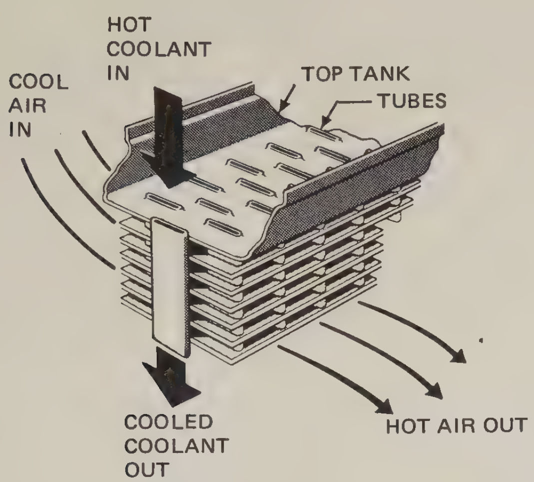


FIG. 19-13 Circulation of air and coolant through a tube-and-fin radiator. *(Union Carbide Corporation)*

○ 19-17 THERMOSTAT A thermostat is located in the passage between the cylinder head and the upper radiator tank. Figure 19-6 shows the thermostat location in the engine. The thermostat contains a temperature-sensitive wax pellet connected to a valve. When the engine is hot, the wax pellet expands, opening the valve to allow coolant to pass freely into the radiator. But when the engine is cold, the wax pellet contracts, closing the valve. This closes the cooling return line to the radiator. Then the coolant in the engine water jackets cannot leave. Therefore, the coolant and the engine both heat up very rapidly. This is desirable, because the engine should heat up as rapidly as possible after starting. When an engine is operated cold, the lubricating oil flows slowly so that moving parts may not be fully lubricated. This promotes excessive wear. Also, water condensation, described in an earlier chapter, takes place and water drips down into the crankcase. All this is minimized by the action of the thermostat.

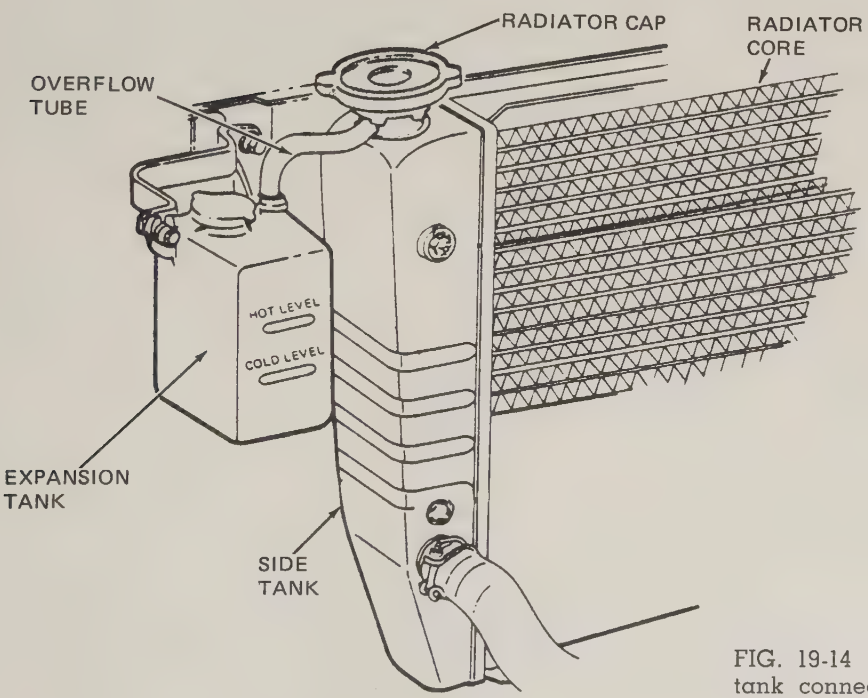


FIG. 19-14 A liquid-cooling system with an expansion tank connected to the radiator.

○ 19-18 PRESSURIZED COOLING SYSTEM Many liquid-cooled engines today have pressurized cooling systems. Water boils at about 212°F [100°C] at sea level. If the pressure on water is increased, it will not boil until a higher temperature is reached. Without pressurizing, the cooling system must be designed to prevent water from reaching 212°F [100°C]. But if the system is pressurized, water temperature can safely go up to almost 250°F [121°C] without boiling. This higher temperature allows the cooling system to operate more efficiently. Each added 1 pound per square inch (psi) [0.07 kg/cm²] increases the boiling point of water about 3¼°F [1.8°C]. Figure 19-15 shows the relationship between pressure and the boiling point of water.

To pressurize a liquid-cooling system, a pressure cap is used on the radiator. A pressure cap is shown in Fig. 19-16. The pressure cap contains two spring-loaded valves. One, called the pressure valve, opens if the pressure gets too high to allow the excessive pressure to escape. The other, the vacuum valve, operates when the engine cools off. When this happens, a partial vacuum can form in the cooling system. The vacuum valve prevents this by opening to admit air from the outside. If a high vacuum formed, it might cause the radiator to partly collapse, pushed in by atmospheric pressure.

Most liquid-cooled engines and some air-cooled engines are equipped with a temperature gauge or indicator light to tell the operator how hot the engine is getting. An abnormal heat rise is a warning to the operator that something is wrong, and the engine must be stopped before serious damage results.

REVIEW QUESTIONS

1. What is the purpose of the engine cooling system?
2. What are the two types of engine cooling systems?

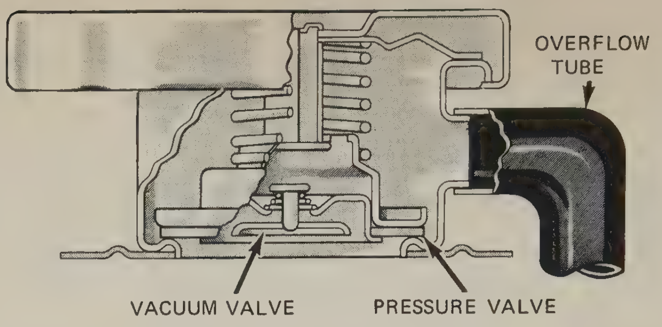


FIG. 19-16 Cutaway view of a radiator pressure cap, showing the pressure valve and the vacuum valve.

3. Give two examples of air-cooled engines.
4. What are water jackets? What are they for?
5. What is the purpose of the water pump?
6. What is the coolant made of?
7. What is the purpose of the engine fan?
8. What is the purpose of the expansion tank?
9. What is the purpose of the thermostat? How does it work?
10. How many valves does the radiator pressure cap have? How do they work?
11. What is the basic purpose of antifreeze?

SELF PROJECTS

1. Whenever you see a liquid-cooled engine, note whether or not the cooling system has an expansion tank. If it does, make a quick sketch showing its location and how it is connected.
2. Examine a cooling-system thermostat. Note the location of the wax pellet which is used in most modern thermostats to close or open the thermostatic valve.

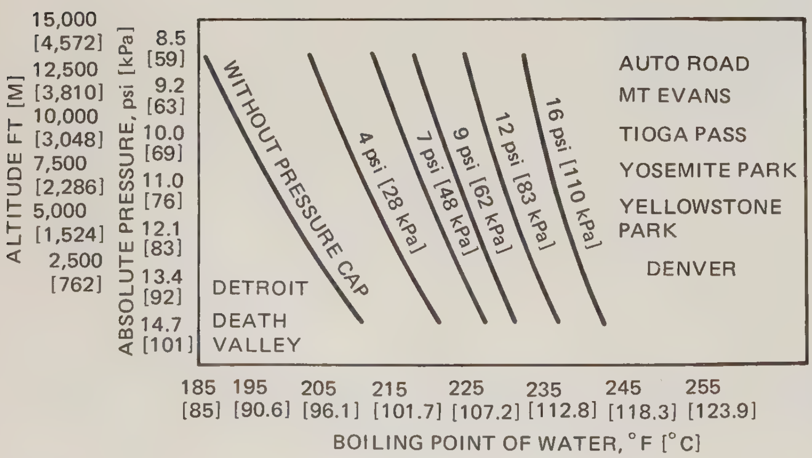
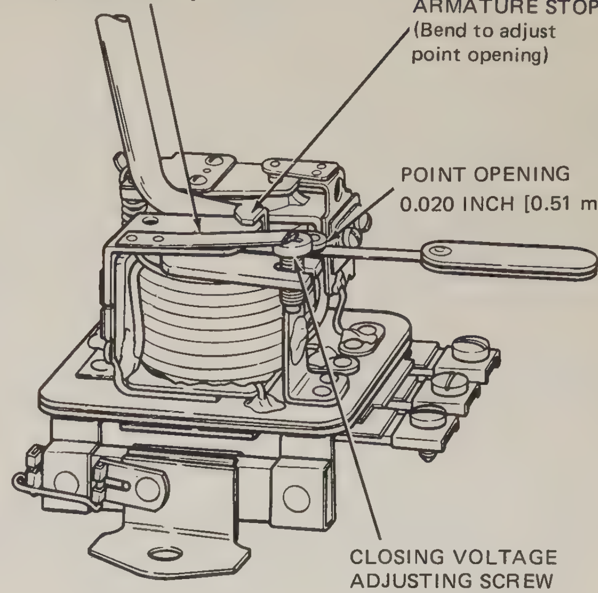


FIG. 19-15 Relationship between pressure and boiling point of water, showing how pressure caps of various capacities can increase the boiling point.

four ELECTRICITY AND ELECTRICAL SYSTEMS

Part Four of *Small-Engine Mechanics* discusses electricity. It explains how the components of the small-engine electrical system work and how they are serviced. There are nine chapters in Part 4. They are as follows:



20 Chapter

Basic Electricity

After studying this chapter, you should be able to:

1. Discuss electricity, electric current, and voltage in terms of electron flow
2. Explain why insulation is needed
3. Describe how magnets and electromagnets work and what lines of force are
4. Explain how diodes and transistors work
5. Draw a schematic diagram of a simple series circuit and of a simple parallel circuit, using the signs and symbols of electricity
6. Explain the difference between a fuse and a circuit breaker

○ 20-1 ELECTRICITY AND SMALL ENGINES A basic job for electricity in small engines is to produce the electric sparks that ignite the compressed air-fuel mixture in the cylinder. The ignition system supplies these sparks, as we explain in a later chapter. When the air-fuel mixture is ignited, it burns to produce the pressure that moves the piston. When the piston moves, the engine produces power.

Many small engines also have electric starters. These are small electric motors that spin the engine crankshaft to start the engine. Most of these electric starting motors are powered by storage batteries. A few are operated by house current (115 volts). We describe batteries, starting motors, and ignition systems in later chapters. Some small-engine applications, such as garden tractors and motorcycles, are equipped with lights and horn in addition to electric starters and batteries.

○ 20-2 WHAT ELECTRICITY IS We described atoms in Chap. 8 and said that atoms had a center, or nucleus, and electrons spinning around this center. When electrons break free from their atoms, they form electricity. Electrons have negative charges. When electrons move from one place to another, there is a flow, or *current* of electricity.

For example, electrons flow easily through a conductor such as a copper wire, as shown in Fig. 20-1. It takes a fantastic number of electrons in motion to produce an electric current strong enough to do any work. The reason is that electrons are so very small. In one ounce of iron, for example, there are approximately 22 million billion billion electrons.

It takes an electrical device such as a battery or a generator to get electrons moving in a conductor. Both the battery and generator can light lights and do other jobs requiring a flow of electric current (electrons). When many electrons are moving, the current is high. When few are moving, the current is low. Following chapters describe starting motors, batter-

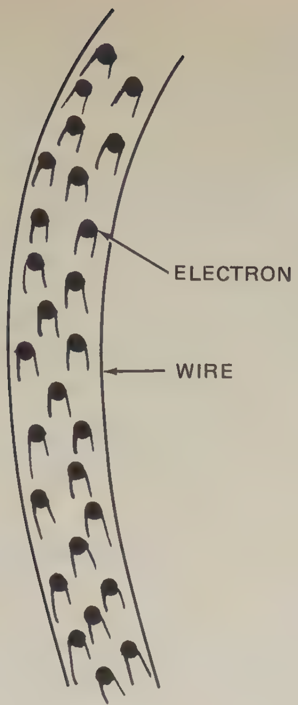


FIG. 20-1 Electric current: electrons moving in a wire.

ies, generators (and alternators), and ignition systems.

○ 20-3 MEASURING CURRENT Current is measured in amperes, or *amps*. One ampere of electric current is a rather small amount of current. The battery can put out 200 to 300 amps when it is operating the starting motor. Headlights may draw 10 or more amps. When you consider how many electrons it takes to make an ampere, an ampere seems like a pretty big amount of electric current. It takes 6.28 billion billion electrons flowing past a point in one second to make 1 amp.

Nobody actually can count electrons to find out how many amperes are flowing in a circuit. An ammeter must be used to measure current flow. The ammeter reports the amount of current flow in amperes.

The ammeter makes use of an interesting effect of electron flow. This effect is that a flow of electrons, or an electric current, produces magnetism.

○ 20-4 MAGNETISM Magnetism comes in two forms: natural and electrical. Both act the same. Natural magnets are made of iron and certain other metals. Magnets attract iron objects. Two facts about magnets that are important are the following:

- Magnets can produce electricity.
- Electricity can produce magnets. Magnets produced by electricity are called *electromagnets*.

We discuss electromagnets in more detail later.

○ 20-5 THE AMMETER Now let us see how the ammeter measures electric current. The simplest kind of ammeter is shown in Fig. 20-2. This is the kind of ammeter found in many lawn tractors and stationary engine installations. Its purpose is to tell the operator whether the alternator is charging the battery or not. The battery will run down if the alternator does not charge the battery when it is supposed to. A run-down battery means no starting, no running engine.

Here is how the ammeter works: The conductor is connected at one end to the battery. The pointer is mounted on a pivot. There is a small piece of iron, oval-shaped, mounted on the same pivot. This oval-shaped piece of iron is called the armature. A permanent magnet attracts the armature and tends to hold it in a horizontal position. In this position, the pointer or needle points to zero. Nothing is happening. Now suppose the alternator starts sending current to the battery. The current passes through the conductor. The current produces magnetism. This magnetism attracts the armature and causes it to swing clockwise. This moves the pointer to the "charge" side. The greater the amount of current flow, the stronger the magnetism and the farther the pointer moves. The meter face is marked off to show the number of amperes flowing.

Now suppose the alternator is not working and you turn on the lights. Current flows from the battery to the lights. The current flows in the reverse direction through the conductor in the ammeter. Now the armature is attracted in the opposite direction, and it swings counterclockwise. This moves the pointer to the "discharge" side. The greater the current flow from the battery, the farther the pointer moves.

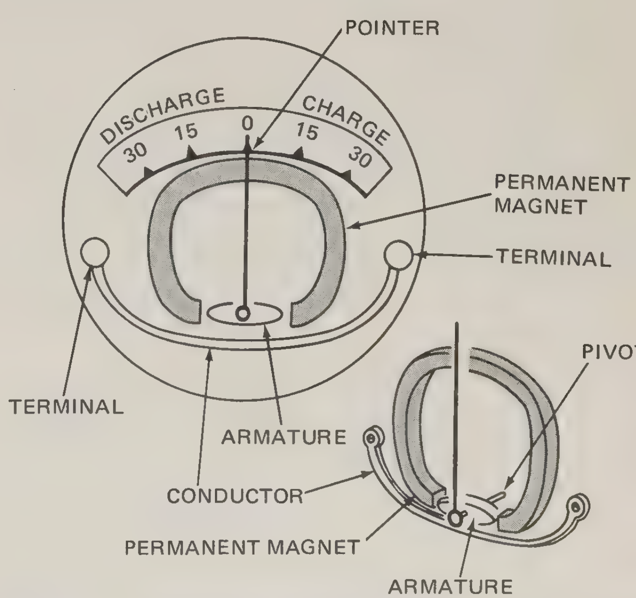


FIG. 20-2 Simplified construction of an ammeter and its interior construction.

○ 20-6 WHAT MAKES ELECTRONS MOVE? Electrons on the move make up electric current. But what makes the electrons move? Simply too many electrons in one spot. When electrons are gathered in one place, they try to move away. The battery and the alternator are devices that collect electrons. They collect electrons at one terminal by taking them away from the other terminal. If we connect the two terminals with a conductor, electrons flow from the terminal with "too many" to the terminal with "too few."

○ 20-7 VOLTAGE Suppose there are a great many electrons at one terminal. And suppose the other terminal has a great shortage of electrons. With this great excess and great shortage, the electric pressure is high. The pressure on electrons to move from the "too-many" terminal to the "too-few" terminal is high.

Electric pressure is measured in volts. High pressure is high voltage. Low pressure is low voltage. Car batteries are 12-volt units; 12 volts is low pressure. The spark at the spark-plug gap is a flow of electrons at high voltage. The voltage there can be 20,000 volts or more. That is high, but not nearly so high as the voltage on power lines. These are the wires that carry electricity from power plants to your home and to factories. The voltage in these lines is in the hundreds of thousands of volts. It could make a spark several feet long.

○ 20-8 INSULATION Wires that carry electric current are covered with insulation. Power lines are hung from long insulators on the power poles or towers. We do not want those electrons to escape. If they escape, electricity is lost. Worse, electrons on the loose can cause serious trouble. For example, damaged insulation on the wires of household appliances can start a fire. Or someone can be electrocuted.

Also, on the engine, there may be wires between the battery, the alternator, and other electrical devices. These wires are all covered with insulation. The insulation is a nonconductor. Insulation will not let electrons—electric current—flow through it. But if this insulation goes bad, the electric current will not flow where it is supposed to. It could take a short cut through the metal of the engine. This is called a short circuit. It can cause all sorts of trouble, as you will see later.

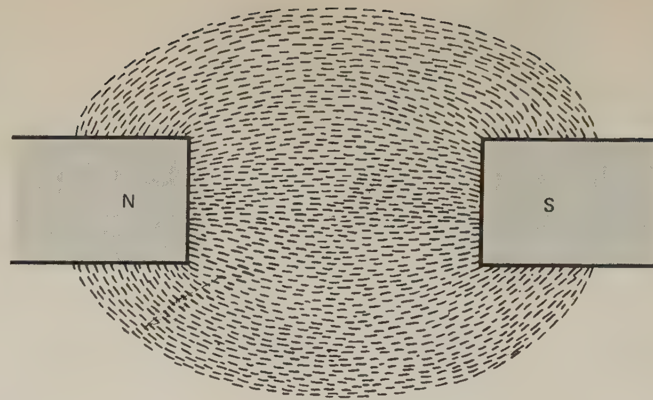


FIG. 20-4 Magnetic lines of force between two unlike magnetic poles. The magnetic lines of force tend to shorten, thus producing the attractive force that pulls the poles together.

Insulation keeps the electric current moving in the proper paths, or circuits. These circuits include the wires and electrical devices on the engine.

○ 20-9 MAGNETS—ANOTHER LOOK Let us take another look at magnets. Magnets act through lines of force. The lines of force stretch between the ends of the magnet. The two ends of the magnet are called the poles, or the magnetic poles. One pole is called the north pole, the other the south pole. The area surrounding the poles, where the lines of force are, is called a magnetic field.

○ 20-10 LINES OF FORCE Lines of force have two properties: One is that they try to shorten themselves. If you hold the north pole of one magnet close to the south pole of another magnet, the two magnets pull together (Fig. 20-3). If we drew the lines of force between the two poles, the picture would look something like Fig. 20-4. The lines of force, stretching between the two poles, try to shorten up and so pull the two poles together.

The other property is that lines of force run more or less parallel to each other. Also, they try to push away from each other. Suppose we bring two like poles together—two north poles, for example (Fig. 20-5). The lines of force run parallel to each other and

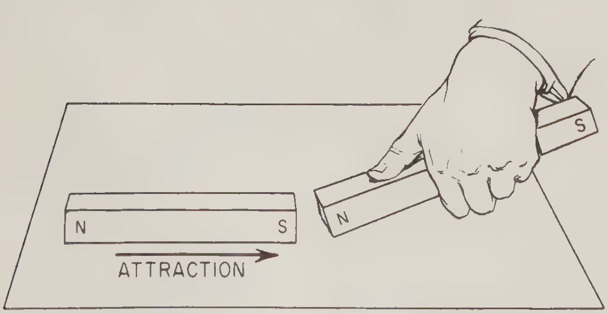


FIG. 20-3 Unlike magnetic poles attract each other.

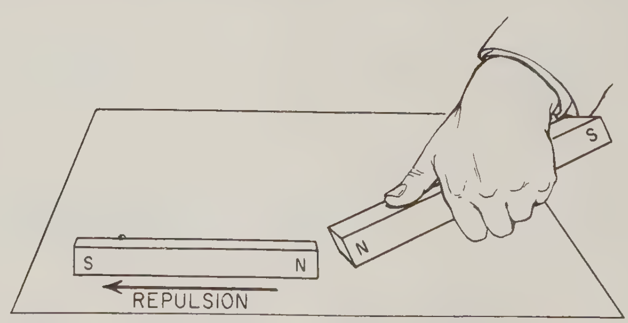


FIG. 20-5 Like magnetic poles repel each other.

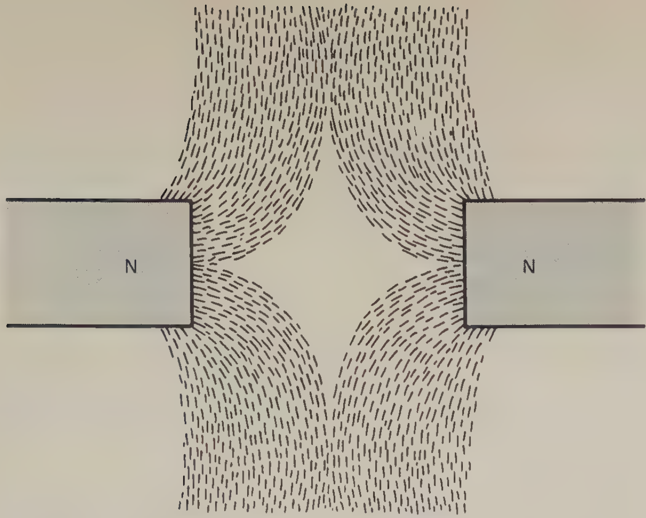


FIG. 20-6 Magnetic lines of force between two like poles. Magnetic lines of force tend to parallel each other, thus forcing the two like poles away from each other.

try to push away. The magnet that is free actually moves away when the like pole of the other magnet is brought close (Fig. 20-6).

So now we can draw these conclusions:

- Like magnetic poles repel each other. North repels north. South repels south.
- Unlike magnetic poles attract each other. North attracts south. South attracts north.

○ 20-11 ELECTROMAGNETS Electromagnets act just like magnets. An electromagnet can be made by wrapping wire around a tube. We saw what happened in the ammeter when current flowed one way or the other through the conductor. The current produced magnetism, or magnetic lines of force.

Current flowing through a single conductor will not produce very much magnetism. But suppose we wind a conductor—a wire—around a tube. Then suppose we connect the ends of the wire to a source of electric current (or electrons). The winding produces strong magnetism. There is a strong magnetic field around the coil of wire.

With current flowing through the winding, the winding acts just like a bar magnet. One end of it will either attract or repel a pole of a bar magnet. One end of the winding is a north pole. The other end is a south pole. You can change the poles by reversing the leads to the source of current. This shows that when electrons flow through in one direction, it makes one of the poles north. But when the electrons flow through in the reverse direction, the poles reverse. The north pole becomes the south pole, and the south pole becomes the north pole.

An electromagnet, such as that made by winding wire around a tube, is also called a solenoid. It is used in several places in the electric system of the small engine. We shall find out more about this later, when we discuss the starting motor, charging system, and ignition system.

○ 20-12 RESISTANCE An insulator has a high resistance to the movement of electrons through it. A conductor, such as a copper wire, has a very low resistance. Resistance occurs in all electric circuits. We want resistance in some circuits so too much current (too many electrons) will not flow. In other circuits, we want as little resistance as possible so that a high current can flow.

Resistance is measured in ohms. For example, a 1000-foot [304.8-m] length of No. 10 wire, which is about 0.1 inch [2.54 mm] in diameter, has a resistance of 1 ohm. A 2000-foot [605.6-m] length has a resistance of 2 ohms. If the wire is heavier, the resistance drops. For example, a No. 4 wire, 0.2 inch [5.08 mm] in diameter, has only 1/4 ohm resistance per 1000 feet [304.8 m].

The longer the path, or circuit is, the farther the electrons have to travel and the higher the resistance to electric current becomes. With the heavier wire, the path is wider. More electrons can flow, and so the resistance is lower.

○ 2-13 OHM'S LAW There is a definite relation between current (electron flow), voltage (electric pressure), and resistance. As the electric pressure goes up, more electrons flow. Increasing the voltage increases the amperes of current. However, increasing the resistance decreases the amount of current that flows. These relationships can be summed up in a statement known as Ohm's law:

Voltage is equal to amperage times ohms

or $$E = IR$$

where E = voltage
I = current, in amperes
R = resistance, in ohms

The main thing about Ohm's law is that it shows that increasing the resistance reduces the current. A major cause of electrical troubles is excessive resistance in circuits. This can be due to poor connections, defective wires, or bad contacts.

○ 20-14 ONE-WIRE SYSTEMS For electricity to flow, there must be a complete path, or circuit. The electrons must flow from one terminal of the battery or alternator, through the circuit, and back to the other terminal. In the automobile and many small-engine installations, the engine and car frame, or engine support, are used as the return circuit. Therefore, no separate wires are required for returns from electrical devices to the battery or alternator. The return circuit is called ground and is indicated in wiring diagrams by the symbol ⏚. The ground—the

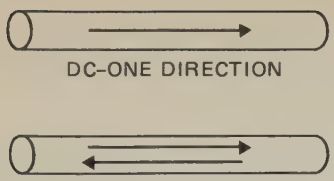


FIG. 20-7 Directions of ac and dc current flow in a wire.

engine and car frame—is the other half of the circuit. It is the return circuit between the source of electricity (battery or alternator) and the electrical device.

○ 20-15 ALTERNATING AND DIRECT CURRENT Most of the electricity generated and used in this world is alternating current (ac). The current flows first in one direction and then in the opposite direction, as shown in Fig. 20-7. It alternates. The current you use in your home is ac. It alternates 60 times per second and therefore is called 60-cycle [60 Hz] ac. (In the metric system of measurement, one cycle per second is called a hertz, abbreviated Hz.)

The battery and other electrical devices used in automobiles and small-engine installations cannot use ac. The battery is a direct-current (dc) unit. When you discharge it by connecting electrical devices to it, you take current out in one direction only. The current does not alternate, or change directions. Likewise, the other electrical devices in the car, motorcycle, or small engine operate on dc only.

○ 20-16 SERIES CIRCUITS In series circuits, each electrical device is connected to other electrical devices in such a way that the same current flows through all, as shown in Fig. 20-8. The whole series of electrical devices is connected together in a single circuit. If any one device is turned off, the circuit is broken and no current can flow through any device in the circuit.

○ 20-17 PARALLEL CIRCUITS In parallel circuits, the various devices are connected by parallel wires, as shown in Fig. 20-9. The current divides, part of it flowing into one device, part into another, and so on.

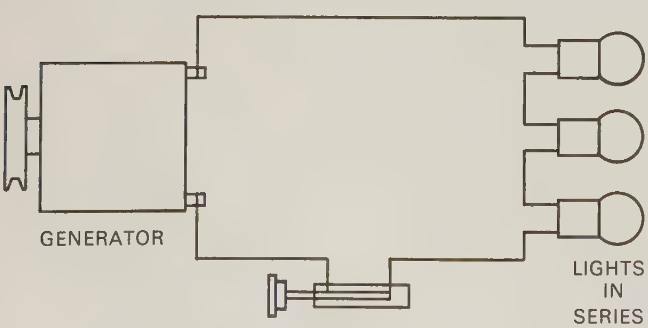


FIG. 20-8 When light bulbs are connected in series, the same current flows through all.

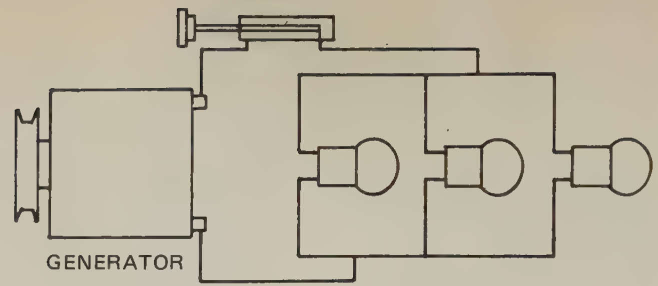


FIG. 20-9 When light bulbs are connected in parallel to the current source, the current divides, part of its flowing through each light bulb.

Practically the same voltage is applied to each device, and each device can be turned on or off independently of the others.

Many small-engine vehicle and motorcycle circuits are series-parallel circuits. For example, even though a pair of headlights are connected to the battery in parallel, both are connected in series to the battery through a lighting switch, as shown in Fig. 20-10.

○ 20-18 RESISTANCE IN PARALLEL AND SERIES CIRCUITS The resistance of a series circuit is the sum of the resistances of the various components of the circuit. In Fig. 20-11, the total resistance, ignoring the wires between the resistors, is 4 + 2 + 5 + 1, or 12 ohms. Using Ohm's law, we can calculate that 1.0 amp will flow from the 12-volt battery through the 12-ohm circuit.

The resistances of parallel circuits are more difficult to calculate. Paralleling devices reduce the resistance, and so more current flows. For example, the headlights of a garden tractor are in parallel in Fig. 20-10. To calculate the resistance of a number of circuits in parallel, use the formula

$$R = \frac{1}{1/r_1 + 1/r_2 + 1/r_3 + 1/r_4 + \cdots + 1/r_n} \text{ ohm}$$

in which R is the total resistance of the group in ohms, and r_1, r_2, r_3, r_4, and so on, are the resistances of the individual circuits.

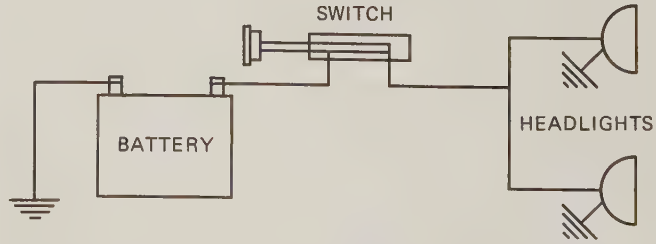


FIG. 20-10 The headlight circuit in a garden tractor is a series-parallel circuit. The two headlights are in parallel with each other but are connected in series with the light switch to the battery.

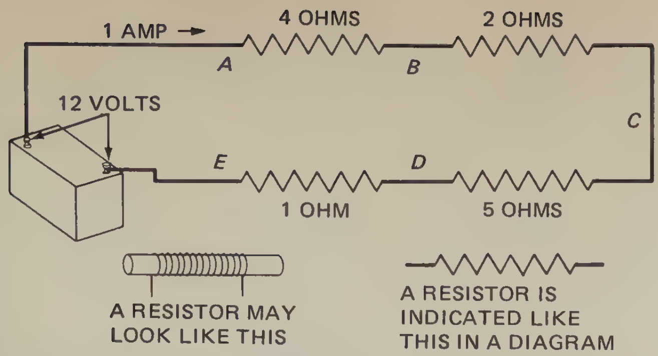


FIG. 20-11 A series circuit made of four resistors of varying resistances.

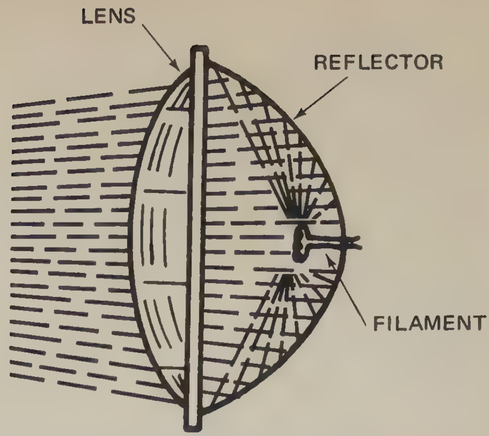


FIG. 20-12 Current flow through the filament of a headlight causes the filament to heat up and glow brightly.

Example: Suppose that the resistance of each of the headlights shown in Fig. 20-10 is 1 ohm. The total resistance would then be

$$R = \frac{1}{1/1 + 1/1} = \frac{1}{1 + 1} = \frac{1}{2} \text{ ohm}$$

Example: As a more complicated example, suppose we had a parallel circuit with three resistors of 1, 2, and 4 ohms. The resistance would be

$$\begin{aligned} R &= \frac{1}{1/1 + 1/2 + 1/4} \\ &= \frac{1}{4/4 + 2/4 + 1/4} \\ &= \frac{1}{7/4} = \frac{4}{7} = 0.57 \text{ ohm} \end{aligned}$$

○ 20-19 VOLTAGE DROP If the voltage across each of the resistors in the circuit shown in Fig. 20-11 were checked with a voltmeter, the voltage would add up to 12 volts. For example, the voltage between A and B, or across the 4-ohm resistor, would be 4 volts, from B to C it would be 2 volts, from C to D it would be 5 volts, from D to E it would be 1 volt. If we did not know the resistance of any of the resistors, we could find it by measuring the voltage and amperage and then using Ohm's law ($R = E/I$). For example, the resistance of resistor AB would be 4 volts divided by 1 amp, or 4 ohms.

The voltage is gradually "used up" from one end of the circuit to the other. The voltage drops 4 volts across the 4-ohm resistor. Thus a voltage measurement between points B and E would be 8 volts, from C to E it would be 6 volts, and from D to E it would be 1 volt. Any resistance in a circuit causes a voltage loss, or voltage drop. The voltage drop is also called the *IR* drop. This comes from the formula $E = IR$.

○ 20-20 RESISTANCE HEATING As electric current flows through a conductor, a heating effect results. Normally, the heating effect is very slight and does no harm. But if the wire is too small, there will be considerable heating. Likewise, a bad connection will become hot.

NOTE: Any connection becoming abnormally hot when current flows through it is in bad condition.

The reason for the heating effect is as follows: Voltage, or electric pressure, causes electrons to hop from one atom to another. There is also a certain amount of "bumping about," and so the atoms proceed to move faster. When atoms move faster, the substance becomes hotter. Fast atom motion means a high temperature. Therefore, the more bumping about the atoms get from a heavier electron flow, the hotter the conductor becomes.

A light bulb is simply a wire conductor, called the filament, in an airtight glass envelope, as shown in Fig. 20-12. When the light bulb is connected to an electric circuit, electrons bombard the atoms in the wire so hard that the filament becomes very hot. It gets so hot that it glows brilliantly and gives off light.

As current passes through a wire, the resistance and the temperature of the wire also may increase. Most metals show this effect. A simple explanation might be this: With increased temperature, the atoms of metal that make up the wire are moving faster. Therefore, the electrons have a harder time jumping between the faster moving atoms.

○ 20-21 WIRING CIRCUITS With the increasing number of electrically operated devices that can be used with a small engine, the wiring circuits have become rather complex. Figure 20-13 shows the wiring diagram for one model of a small engine. On some engines, the wires between the components are bound together into wiring harnesses. Each wire is marked by special colors in the insulation—for example, light green, dark green, blue, red, black with a white tracer, and so on. These markings make identification of the various wires easier.

The wires connecting electrical components and instruments usually are fastened together by termi-

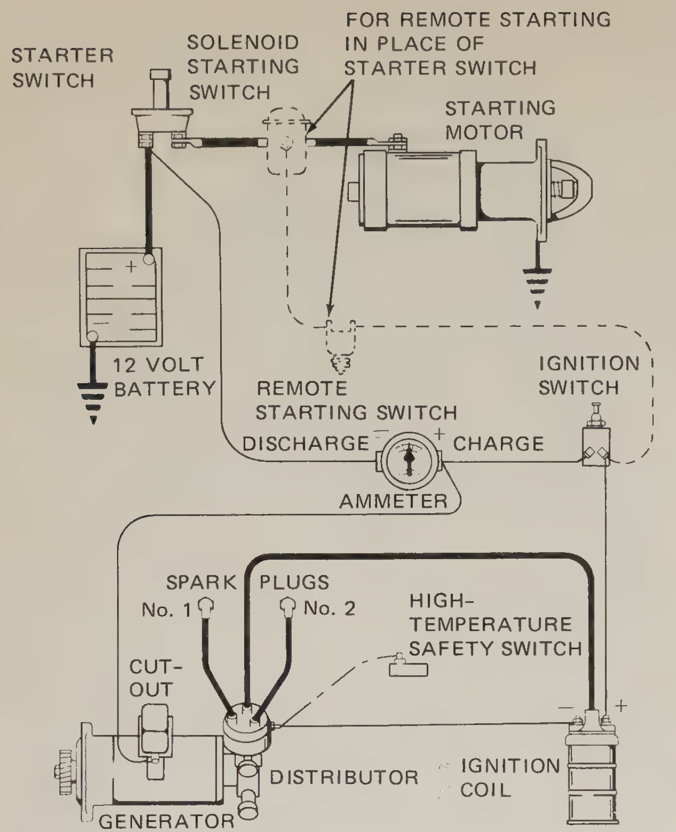


FIG. 20-13 Wiring diagram of a small engine that has battery ignition and a dc generator charging system. *(Wisconsin Motor Corporation)*

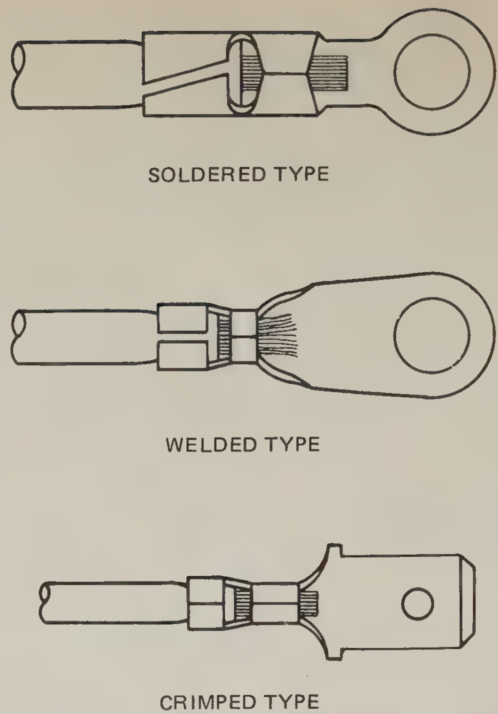


FIG. 20-14 Types of wire terminals.

nals attached to the ends of the wire. Figure 20-14 shows various types of terminals. Use of terminals and connectors makes disassembly and assembly operations of wires and electrical devices faster and easier. Many types of connectors are available for use in the shop. One advantage of many connectors is that they may be used to splice and tap into a wire without your having to strip insulation, solder, or tape the bare connection afterwards. Figure 20-15 shows how a connector can be used to tap into a wire. Notice that the only tool used is regular pliers.

In electrical work, abbreviations and symbols are used constantly. Symbols are a kind of shorthand. Their use permits large and complicated electrical systems to be accurately drawn in schematic form. As you work in the small-engine service field, you will find many different types of drawings and illustrations. There, you will have to understand and interpret. Figure 20-16 shows many of the widely used electrical symbols that you may find in manufacturers' manuals. Should you see in an illustration a symbol that is not on this list, look carefully through the book to find the caption for symbols used.

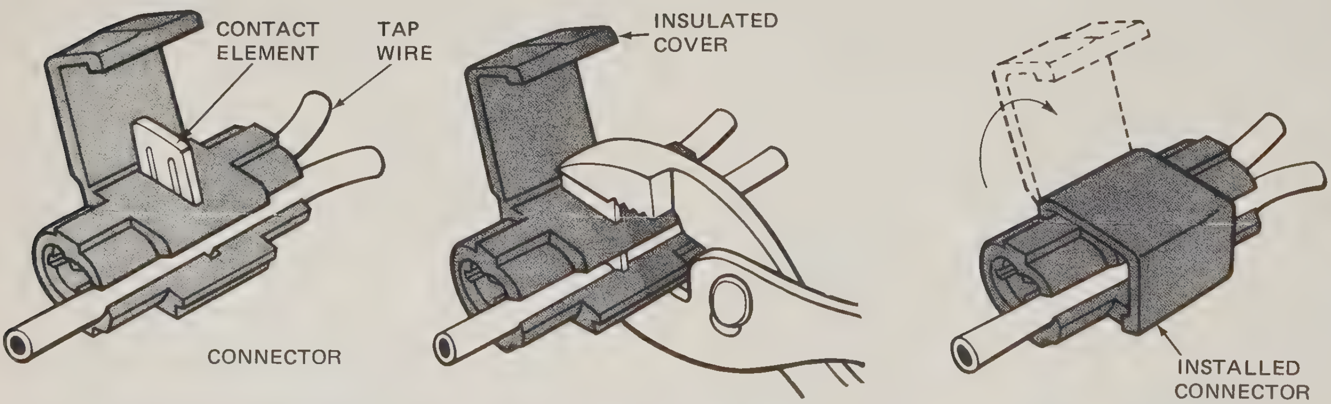


FIG. 20-15 To tap into a wire using a connector, *(a)* slide the open side of the connector on the wire and position the tap wire in the connector. *(b)* Squeeze the contact element down with pliers. *(c)* Close the connector cover and snap it in place to provide insulation. *(3M Company)*

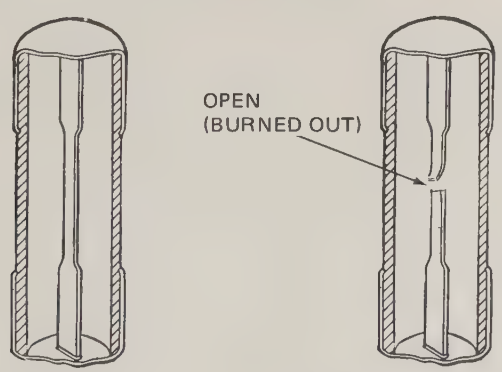
ELECTRICAL SYMBOLS			
SYMBOL	REPRESENTS	SYMBOL	REPRESENTS
A	AMMETER		GROUND—CHASSIS FRAME (Preferred)
	BATTERY—ONE CELL		GROUND-CHASSIS FRAME (Acceptable)
	BATTERY—MULTICELL		LAMP or BULB (Preferred)
12 V ± –	(Where required, battery voltage or polarity or both may be indicated as shown in example. The long line is always positive polarity.)		LAMP or BULB (Acceptable)
		MOT	MOTOR—ELECTRICAL
	CABLE—CONNECTED	—	NEGATIVE
+ or	CABLE—NOT CONNECTED	+	POSITIVE
	CAPACITOR		RESISTOR
	CONNECTOR—FEMALE CONTACT		SWITCH—SINGLE THROW
	CONNECTOR—MALE CONTACT		SWITCH—DOUBLE THROW
	CONNECTORS—SEPARABLE—ENGAGED		TERMINATION
	FUSE	V	VOLTMETER
GEN	GENERATOR	or	WINDING—INDUCTOR

FIG. 20-16 Commonly used electrical symbols. *(General Motors Corporation)*

○ 20-22 FUSES AND CIRCUIT BREAKERS Most electric circuits have fuses or circuit breakers that protect the electrical components from damage due to a short circuit or ground.

The typical fuse is the cartridge type shown in Fig. 20-17. It consists of a glass envelope, contact caps on each end, and a strip of soft metal connecting the two contact caps. The fuse is connected in series into the circuit. If a short or ground develops in the circuit and excessive amounts of current begin to flow, the high current overheats the soft metal strip. This melts the strip (or the fuse "blows"), and the circuit is opened as shown in Fig. 20-17*b*. When this happens, the circuit should be checked so that the short or ground can be eliminated. Then a new fuse should be installed.

Circuit breakers perform the same function as fuses except that they do not "blow." Therefore, circuit breakers do not require replacement when an overload occurs. Instead, they cause contact points to open, interrupting the circuit. When the overload condition is eliminated, the contact points close to complete the circuit again.



(*a*) GOOD FUSE (*b*) BLOWN FUSE

FIG. 20-17 A cartridge fuse.

REVIEW QUESTIONS

1. What do you call a flow of electrons all moving in the same direction in a wire?
2. Name two sources of electric current in small engines.
3. The ampere is a measurement of what?
4. Can magnets produce electricity?
5. Can electricity produce magnets?
6. What device is used to measure current?
7. What makes electrons move in a wire?

8. What is voltage?
9. What is the purpose of insulation?
10. What is a short circuit?
11. What are the two ends of a magnet called?
12. Do like magnetic poles attract or repel each other?
13. Do unlike magnetic poles attract or repel each other?
14. Explain how to make an electromagnet.
15. What is resistance? How is it measured?
16. What is Ohm's law?
17. What is one of the major causes of electrical troubles in engine electric systems?
18. Explain what a one-wire system is. Why is it an advantage to have a one-wire system?
19. What is dc?
20. What is ac?

SELF PROJECT

Refer to Fig. 20-13 and make a list of all the electrical units you see in the illustration. File this list in your notebook.

21 Chapter

Batteries

After studying this chapter, you should be able to:

1. **Explain the purpose of the battery in the engine electrical system**
2. **Explain how batteries are constructed and how they work**
3. **Describe the various battery ratings and explain what they mean**
4. **Define "ni-cad battery"**

○ 21-1 PURPOSE OF BATTERY The battery (Figs. 21-1 and 21-2) supplies current to operate the starting motor for starting the engine. It also supplies current for lights and other electrical devices in use when the engine is not turning the alternator or generator fast enough. The alternator or generator has to be turning above a minimum speed to supply enough current to handle any electrical loads that are turned on. The amount of current the battery can supply is limited by the *capacity* of the battery. The capacity, in turn, depends on the amount of chemicals the battery contains.

○ 21-2 CHEMICALS IN THE BATTERY Figure 21-3 shows a battery in cutaway view. The chemicals in the battery are sponge-lead (a solid), lead oxide (a paste), and sulfuric acid (a liquid). These three substances are made to react chemically to produce a flow of current. The lead oxide and sponge lead are held in *plate grids* to form positive and negative plates.

The plate grid (Fig. 21-4) is a framework of antimony-lead alloy with horizontal and vertical bars. The plate grids are made into plates (Fig. 21-5) by applying lead oxide paste. The horizontal and vertical bars hold the paste in the plate.

○ 21-3 BATTERY CONSTRUCTION In the battery, several similar plates are properly spaced and welded, or lead-burned, to a strap, forming a plate group (Fig. 21-5). Plates of two types are used: one for the positive plate group, the other for the negative plate group. A positive plate group is nested with a negative plate group. Separators are placed between the groups to form an element (Fig. 21-5). The separators hold the plates apart so that they do not touch.

The elements are placed in cells in the battery case. Then heavy lead connectors are attached to the cell terminals to connect the cells in series. Many batteries have connectors that pass through the par-

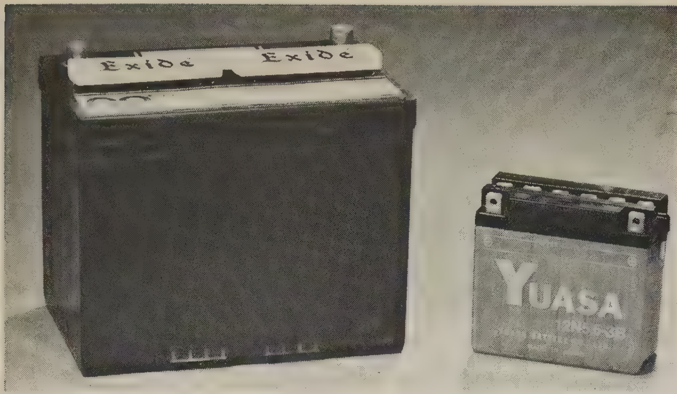


FIG. 21-1 Comparative size of automobile and motorcycle batteries.

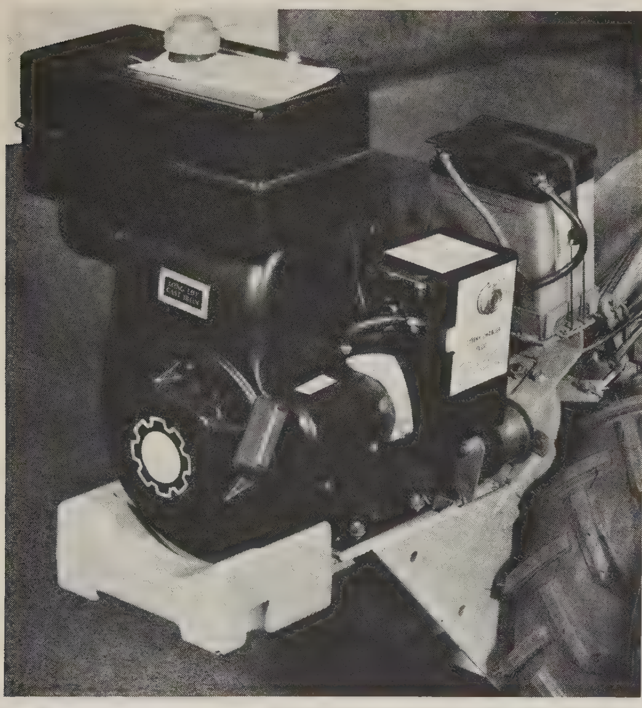


FIG. 21-2 Location of the battery and starting motor on a tiller. *(Ariens Company)*

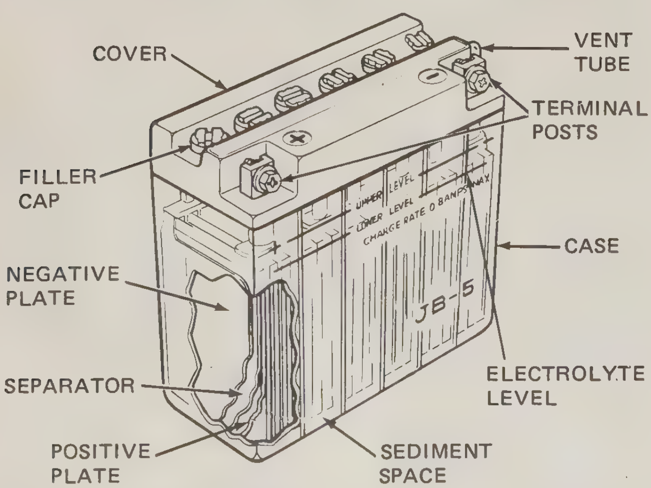


FIG. 21-3 Cutaway view of a battery. *(Lawn Boy Division of Outboard Marine Corporation)*

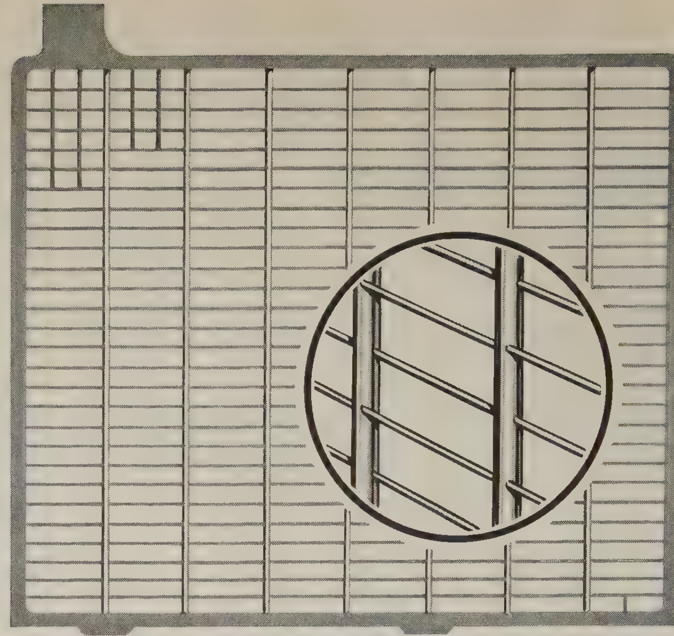


FIG. 21-4 Battery plate grid.

titions, as in Fig. 21-6. Others have connectors that go over the partitions. After the internal connectors are in place, the cover is put on. The cover has openings through which liquid can be added when the filler plugs or vent caps are removed. After the liquid is added and the battery is given the initial charge, it is ready for operation.

Some batteries have the two main terminals on the battery cover, as in Figs. 21-1 and 21-6. Other batteries have the terminals in the side of the battery case, as in Fig. 21-7. This type of battery is called an ST (for the side terminal or sealed terminal) battery by the manufacturer. Figure 21-8 shows how the cables are connected to the ST battery. Figure 21-9 shows the battery mounting arrangement for a motorcycle-type battery.

There is also a "no-service" battery, which is sealed (Fig. 21-10). It never requires the addition of water, as other batteries occasionally do.

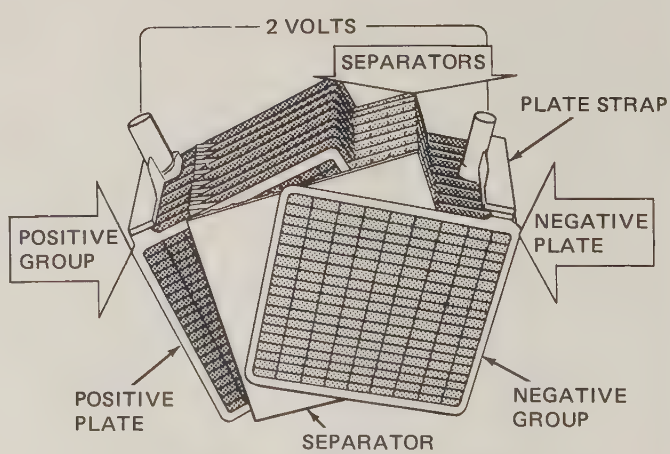


FIG. 21-5 Partly assembled battery element.

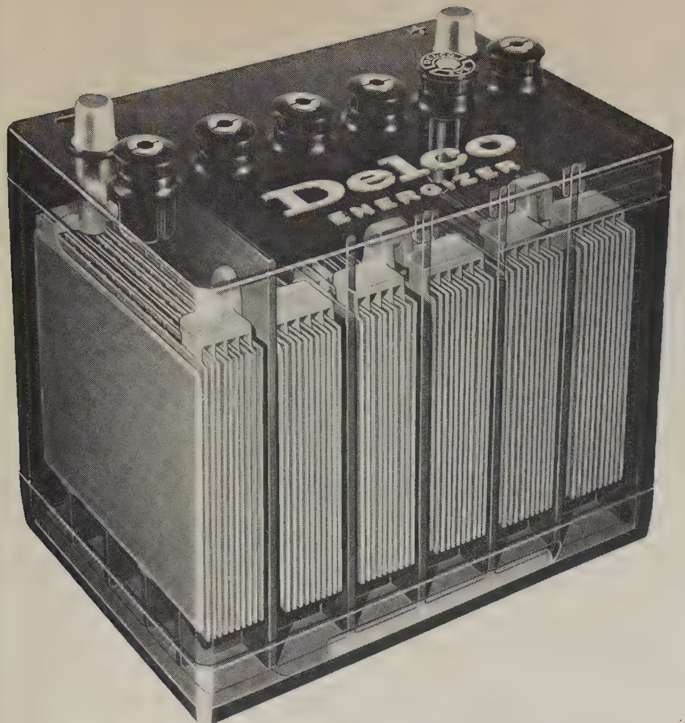


FIG. 21-6 Phantom view of a 12-volt storage battery. The case is shown as though it were transparent so that the construction of the cells can be seen. *(Delco-Remy Division of General Motors Corporation)*

○ 21-4 VENTS When the battery is discharged, as current is taken from it, chemical changes take place in the battery. Also, when the battery is charged from a source of electric current, other chemical changes result in the battery. Gases are produced by these chemical changes. These gases must be released from the battery through vents. In some batteries, the vents are in the vent plugs or caps. Figure 21-11 shows, in sectional view, a typical vent plug. It has baffles which separate liquid droplets from the gas. The liquid drops back down into the battery. The gas escapes through the vent hole.

In motorcycle-type batteries, a special breather tube is used as the vent for all cells (Fig. 21-9). The location of the battery (Fig. 21-2) requires this type of venting. It would be very undesirable to have vent plugs of the type shown in Fig. 21-11 releasing gases close to the operator. The gas released by a battery while it charges is hydrogen, and it can explode if ignited.

Even though the no-service batteries are sealed as shown in Fig. 21-10, they also are vented through a small, well-baffled hole. The vent hole prevents battery damage from a gas-pressure buildup inside it.

○ 21-5 CHEMICAL ACTIVITIES IN THE BATTERY The liquid in a battery is called the electrolyte. It is made up of about 40 percent sulfuric acid and about 60 percent water (in a fully charged battery). When sulfuric acid is placed between the plates, chemical

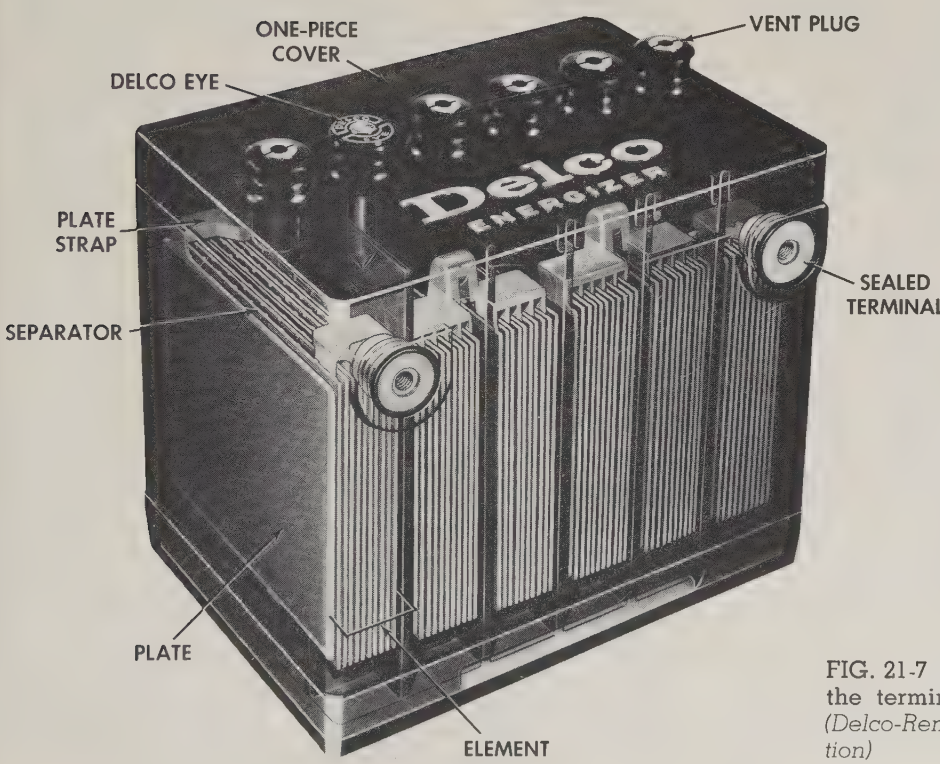


FIG. 21-7 Phantom view of a 12-volt battery with the terminals in the side of the battery case. *(Delco-Remy Division of General Motors Corporation)*

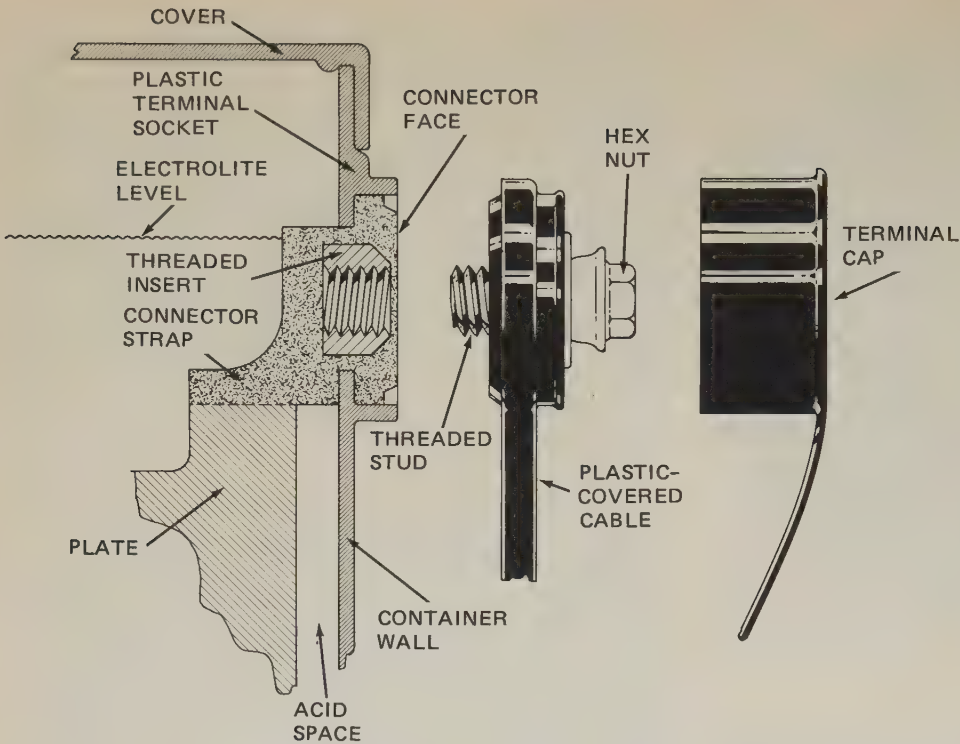


FIG. 21-8 Sectional view showing construction of a side-terminal battery with the cable, stud, and terminal cap assembly. *(Gould, Inc.)*

actions take place. These actions remove electrons from one group of plates and collect them at the other. This creates a 2.1-volt pressure between the two groups of plates. There is an electrical pressure of 2.1 volts between the two terminals of the battery cell. If the two terminals are not connected by any circuit, no further chemical activity takes place.

However, when the two terminals do become connected by an electric circuit, electrons (current) will flow. They flow from the terminal where chemical activity has collected them. They flow through the circuit to the other terminal, where the chemical activity has removed them. Chemical activities now begin again and so the 2-volt pressure is maintained. The current flow continues. The chemical actions "use up" the sponge lead, lead peroxide, and sulfuric acid. After a certain amount of current has been withdrawn, the battery is discharged (or "run down" or "dead"). It is not capable of delivering any additional current. When the battery has reached this state, it can be recharged. This is done by supplying it with a flow of current from some external source. The external source forces current back through the battery. This reverses the chemical activities in the battery. The plates are restored to their original composition, and the battery becomes recharged. Then it is ready to deliver additional current.

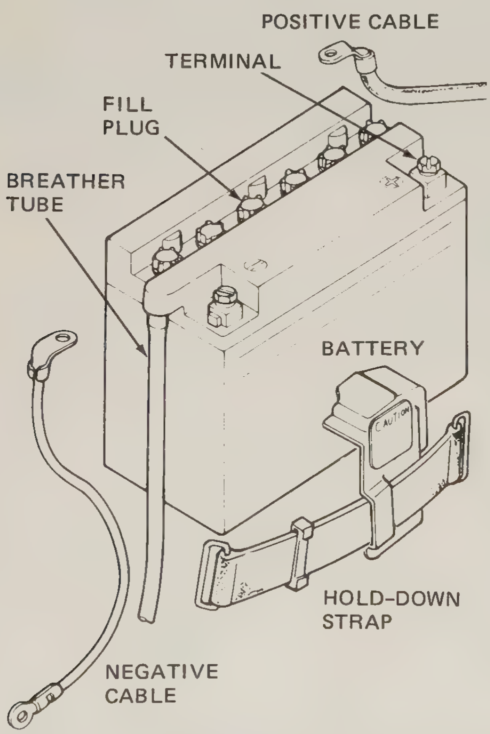


FIG. 21-9 A motorcycle battery that has screw-type terminals. *(Honda Motor Company, Ltd.)*

○ 21-6 CONNECTING CELLS Cells are connected in series so that their voltages add. Three cells connected in series make a 6-volt battery. Six cells connected in series make a 12-volt battery. Most automotive and motorcycle-type batteries are 12-volt batteries. Some small-engine applications require 6-volt batteries. Some heavy-duty applications such as trucks and buses may require two 12-volt batteries connected in series to produce 24 volts.

Actually, a battery cell at 80°F [26.7°C] will test on open circuit at about 2.1 volts when fully charged. Common practice, however, is to call it 2 volts.

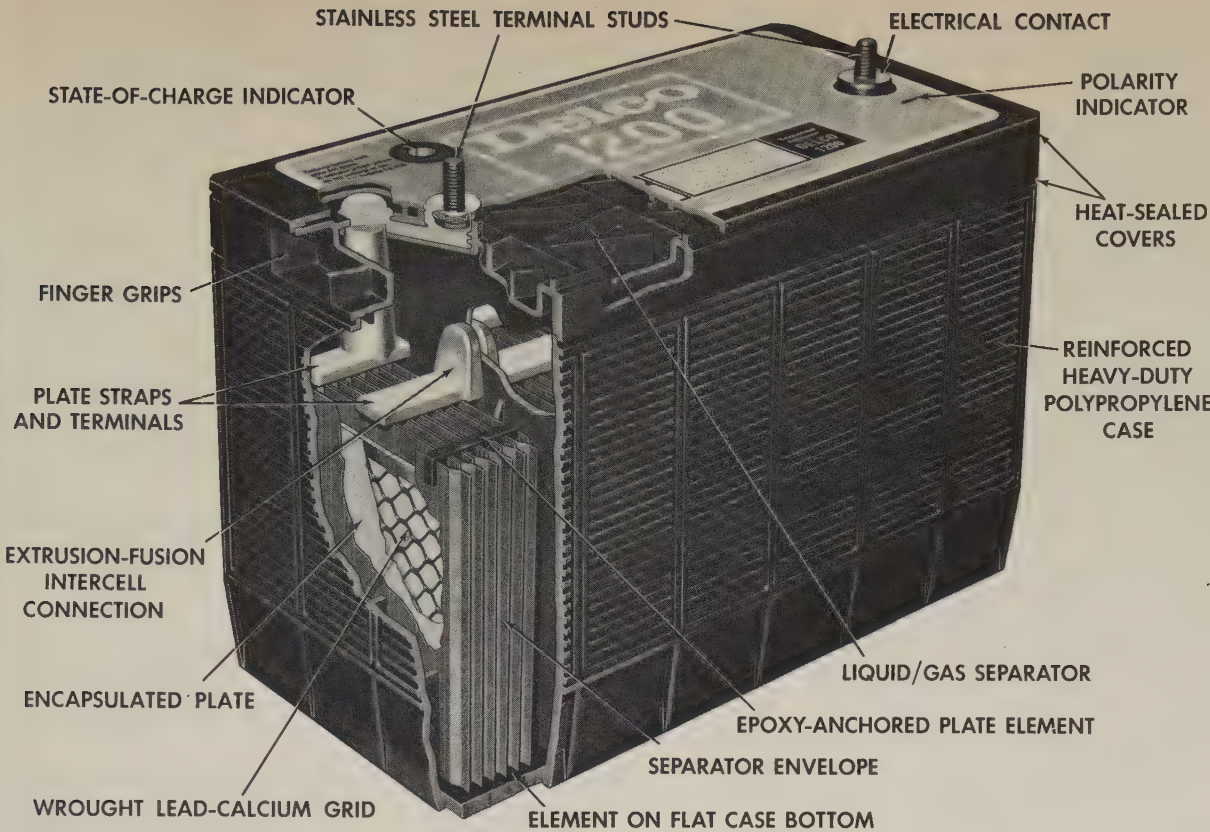


FIG. 21-10 Sealed battery of the type that never requires water. *(Delco-Remy Division of General Motors Corporation)*

Therefore, a six-cell battery is said to be a 12-volt battery, rather than a 12.6-volt battery.

○ 21-7 BATTERY RATINGS The amount of current that a battery can deliver depends on the area and volume of the active plate material. It also depends on the amount and strength of electrolyte. Batteries are rated several different ways. Probably the most common rating is the ampere-hour capacity.

○ 21-8 BATTERY EFFICIENCY The ability of the battery to deliver current varies within wide limits. It depends on temperature and rate of discharge. At low temperature, chemical activities are greatly reduced. The sulfuric acid cannot work so actively on the plates. The battery is less efficient and cannot supply as much current for as long a time. High rates of discharge will not produce as many ampere-hours as low rates of discharge. At high discharge rates, the chemical activities take place only on the surfaces of the plates. They do not have time to penetrate the plates and to use the materials below the plate surfaces.

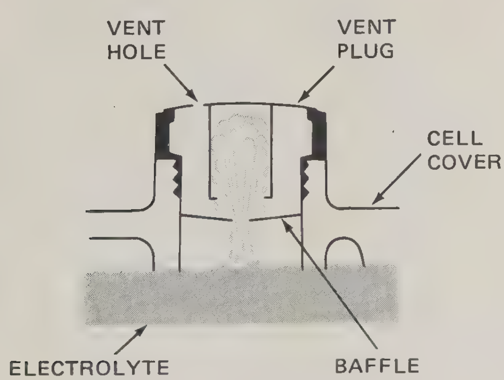


FIG. 21-11 A vent plug in cell cover has a small vent hole to allow gases to escape. *(Delco-Remy Division of General Motors Corporation)*

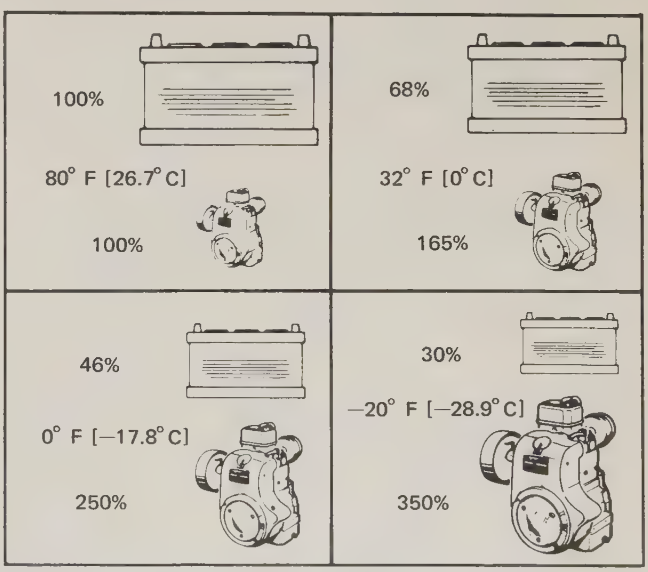


FIG. 21-12 Battery power shrinks while cranking power required increases with falling temperature. *(Tecumseh Products Company)*

Figure 21-12 relates battery temperature to the cranking power required by the engine. These figures are only approximations.

○ 21-9 VARIATIONS IN TERMINAL VOLTAGE

Because the battery produces voltage by chemical means, the voltage varies according to a number of conditions. These conditions and their effect on the battery voltage may be summed up as follows:

1. The terminal voltage of a battery that is being charged increases with the following:
   a. Increasing charging rate. To increase the charging rate (amperes input), the terminal voltage must go up.
   b. Increasing state of charge. As the state of charge goes up, the voltage must go up to maintain the charging rate. For example, a voltage of approximately 2.6 volts per cell is required to force a current through a fully charged battery. This is the reason that voltage regulators are set to operate at 15 volts—slightly below the voltage required to charge a fully charged battery. This setting protects the battery from overcharge.
   c. Decreasing temperature. Lower battery temperatures require a higher voltage to maintain the charging rate.
2. The terminal voltage of a battery that is being discharged decreases with the following:
   a. Increasing discharge rate. As the rate of discharge goes up, the chemical activities increase and cannot penetrate plates so effectively. Therefore, the voltage is reduced.
   b. Decreasing state of charge. With less of the active material and sulfuric acid available, less chemical activity takes place, and the voltage drops.
   c. Decreasing temperature. With lower temperatures, the chemical activities cannot go on as effectively and the voltage drops.

○ 21-10 NICKEL-CADMIUM BATTERIES

Another type of battery is used to operate the starting motor of some small engines. This type of battery is the nickel-cadmium, or ni-cad battery. It is smaller than a lead-acid battery, (discussed in ○ 21-2 through ○ 21-9) of the same capacity. Therefore, the ni-cad battery can be used with certain equipment that does not have room for a lead-acid battery. Figure 21-13 shows the ni-cad battery attached to the handle of a lawn mower. Like the lead-acid battery, the ni-cad battery is rechargeable.

When the key is placed in the starting switch and turned to start, the battery supplies power to the starter, which cranks the engine. In the operation, this system is the same as the starting system that uses a regular 12-volt battery (discussed in Chap. 23).

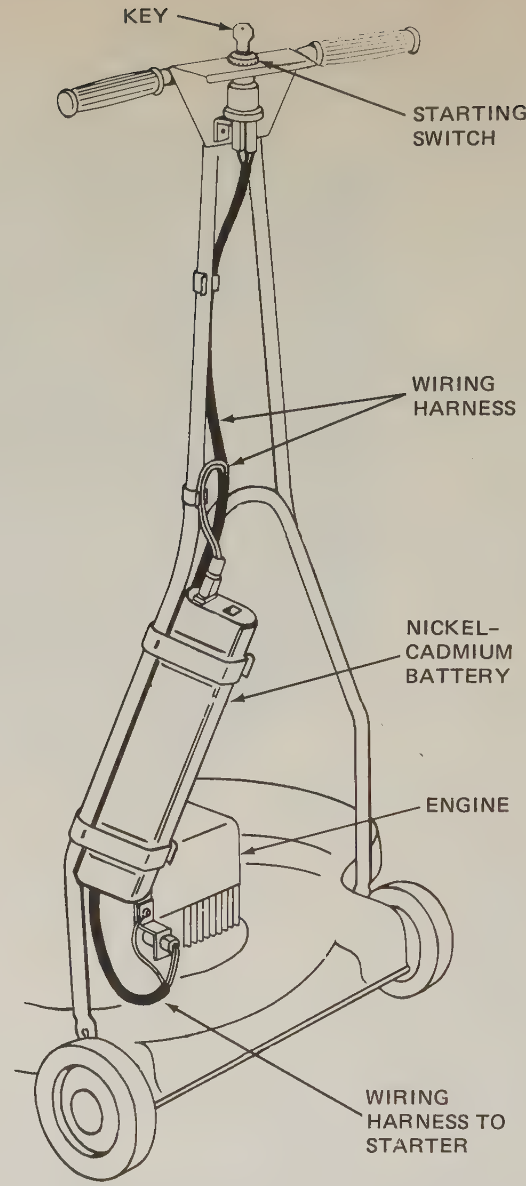


FIG. 21-13 A lawn mower that uses a nickel-cadmium battery to operate the starter. *(Briggs & Stratton Corporation)*

In normal use, the ni-cad battery will provide 40 to 60 starts of the engine before the battery must be recharged.

○ 21-11 NI-CAD BATTERY CONSTRUCTION

As in the lead-acid battery, the cell is the basic unit of the ni-cad battery. The voltage of a ni-cad cell is about 1.2 volts. Each cell consists of positive and negative plates, separators, electrolyte, and cell container. The active material in the plates is nickel hydroxide. After the plates are formed and cut to size, a nickel tab is welded to a corner of each plate. Then the plates are assembled, with the tabs welded to the proper terminals. The plates are separated from each other by a continuous strip of porous plastic.

The electrolyte used in the nickel-cadmium battery is a 30 percent (by weight) solution of potassium hydroxide (KOH) in distilled water. The specific gravity of the electrolyte remains between 1.240 and 1.300 at

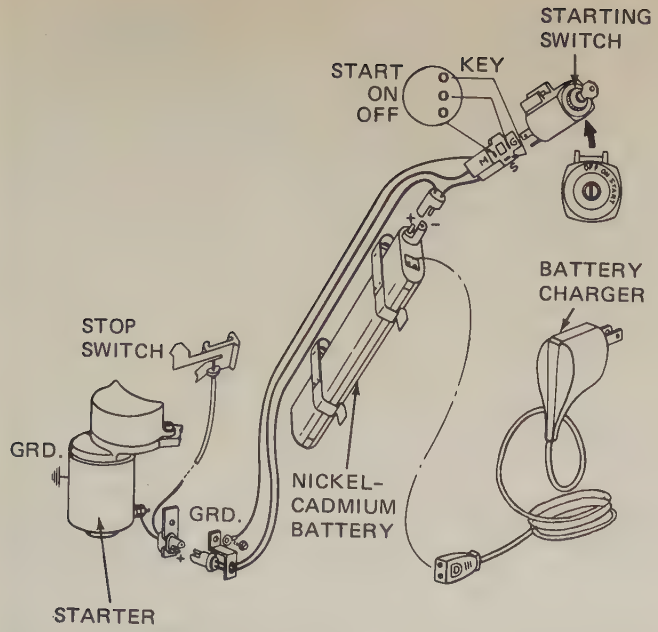


FIG. 21-14 A starting system using a nickel-cadmium battery includes a special battery charger. *(Briggs & Stratton Corporation)*

room temperature. Little change occurs in the electrolyte during charge or discharge. As a result, the battery state of charge cannot be determined by a specific gravity check of the electrolyte. On most small engines, the batteries are completely sealed. There is no way to get to the electrolyte to check its specific gravity or to add water.

When a ni-cad battery needs recharging, the special trickle charger that comes with it (shown in Fig. 21-14) must be used. The charger is plugged into a 120-volt household outlet and then connected to the battery. It takes 14 to 16 hours to fully charge a ni-cad battery. The battery should not be put on the charger if the temperature is below 40°F [4.4°C].

Continual charging within the temperature limits of 40 to 105°F [4.4 to 40.6°C] will not damage a ni-cad battery. The battery always is discharged when it is shipped. Before it will work, it must be charged. You can check the condition of the ni-cad battery with a voltmeter. A typical ni-cad battery used on small engines consists of 10 cells packaged in five sticks, as shown in Fig. 21-15. A fully charged battery of this type will have a voltage reading of 12.0 to 12.5 volts.

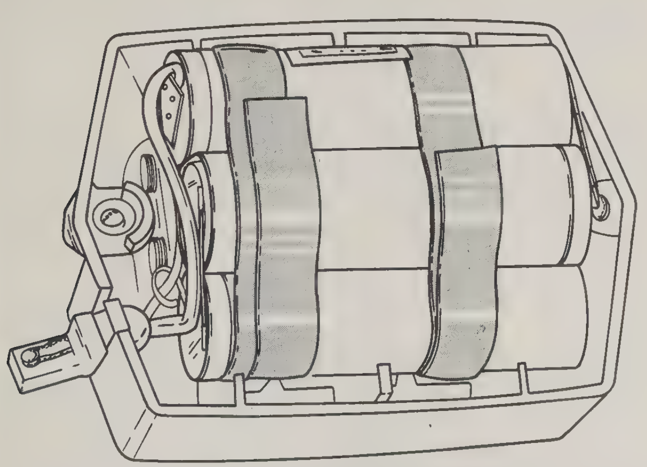


FIG. 21-15 A typical ni-cad battery, consisting of 10 cells packaged in five sticks. *(Lawn Boy Division of Outboard Marine Corporation)*

CAUTION: Only the trickle type of battery charger that comes with the ni-cad battery should be used to charge it. This special charger limits the charging current to 100 milliamps, a very small amount of current. Use of any other battery charger may cause the battery to explode, possibly injuring you or anyone else nearby and destroying the battery.

REVIEW QUESTIONS

1. What is the purpose of the battery?
2. What are the three substances that react in the battery to produce current?
3. What are the two types of battery plates?
4. What is placed between the two sets of plates in a battery cell?
5. What are the two locations of the battery terminals?
6. Describe the chemical actions that take place during battery discharge.
7. Describe the chemical actions that take place during battery charge.
8. What is the reserve capacity of a battery?
9. Name three things that cause the battery terminal voltage to increase during battery charging.
10. Name three things that cause the battery terminal voltage to go down during battery discharging.
11. What is a ni-cad battery?
12. What is the voltage of each cell in a ni-cad battery?
13. Why does the ni-cad battery require a special battery charger?

SELF PROJECT

Make a collection of battery advertisements from magazines, newspapers, and catalogs. Note the specific features that each battery has and that make each battery different from others. After studying these advertisements, file the best in your notebook. In addition to obtaining much valuable information about batteries, you will begin to learn the types of batteries manufactured by the various manufacturers.

22
Chapter

Battery Service

After studying this chapter, you should be able to:

1. **List the steps in battery maintenance**
2. **Demonstrate how to check electrolyte level and add water**
3. **Demonstrate how to check a battery with a hydrometer and how to adjust and interpret the readings**
4. **Explain the various factors that affect the specific gravity of the electrolyte**
5. **List the various battery troubles and their possible causes**
6. **Demonstrate how to connect a battery charger and how to charge a battery**
7. **Demonstrate how to jump-start an engine that has a dead battery**

○ 22-1 BATTERY MAINTENANCE Most people tend to forget about the battery in their car, tractor, or motorcycle. They forget it until one cold morning when the battery won't do its job and the engine won't start. Battery failure is one of the more common engine troubles.

If people would have the battery checked once in a while, much of this battery trouble could be avoided. Here are the things that should be done:

1. Visually inspect the battery.
2. Check the electrolyte level in all cells periodically.
3. Add water if the level is low.
4. Clean off corrosion around battery terminals and top.
5. Check the battery condition with a tester. We describe battery testers in later sections.
6. Recharge the battery if it is low.

CAUTION: Sulfuric acid, the active ingredient in battery electrolyte, is very corrosive. It can destroy most things it touches. It will cause serious and painful burns if it gets on the skin. It can cause blindness if it gets into the eyes. If you get battery acid (electrolyte) on your skin, flush it off at once with water. Continue to flush for at least five minutes. Put baking soda (if available) on the skin. This will neutralize the acid. If you get acid in your eyes, flush your eyes out with water, over and over again. Get to a doctor at once! Do not wait!

CAUTION: The gases that form in the tops of battery cells during charging are very explosive. Never light a match or a cigarette near a recently charged battery. Never blow off a battery with an air hose. The

compressed air could lift the cell cover and splash electrolyte all over you or someone nearby.

○ 22-2 VISUAL INSPECTION OF BATTERY Look the battery over for signs of leakage, cracked case or top, corrosion, missing vent plugs, and loose or missing hold-down clamps. Leakage signs, which could indicate a cracked battery case, include white corrosion on the battery carrier or on surrounding metal parts of the machine. If the top of the battery is covered with corrosion and if the owner complains that the battery needs water frequently, the battery probably is being overcharged. This means a check of the charging system should be made.

The most common cause of a cracked top is improper installation. If the wrong wrench is used to remove or tighten the cable clamps, the battery top probably will be broken. See ○ 22-16 on how to remove and replace cable clamps.

The most common cause of a cracked case is excessive tightening of the hold-down clamps.

○ 22-3 CHECKING ELECTROLYTE LEVEL AND ADDING WATER To check the electrolyte level in most batteries, remove the vent caps and look down into the cells. If water is needed, add it. Distilled water is recommended, but any water that is fit to drink may be used.

Battery cells on sealed batteries cannot be checked. But make sure connections are tight at the terminals.

Many batteries have rings in the cell covers which show whether or not the battery needs water. The ring looks as shown in Fig. 22-1. The figure shows the ring when the level is too low and when it is correct.

Many batteries have a *Delco Eye*, a special vent cap or plug, in one of the six cells. It has a transparent rod extending down into the cell. When the end of the rod is immersed, the exposed top of the rod shows black. When the level of the electrolyte falls below the tip, the top of the rod glows. This means water should be added. On this type battery, vent caps do not need to be removed to check electrolyte level.

CAUTION: Do not add too much water. Too much water will cause the electrolyte to leak out. This will corrode, or eat away, the battery carrier and any other metal around.

○ 22-4 CLEANING CORROSION OFF THE BATTERY Battery terminals, especially those located on the top of the battery, tend to corrode (Fig. 22-2). This corrosion builds up around the battery and the battery clamps and also, unseen, between the terminal posts and clamps. To get rid of it and to clean the battery top, mix some common baking soda in a can

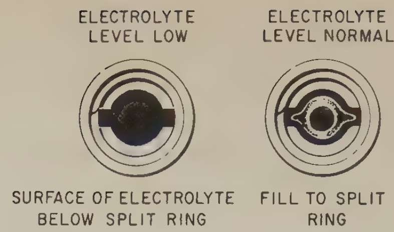


FIG. 22-1 Appearance of the electrolyte and split ring when the electrolyte level is too low and when it is correct. *(Delco-Remy Division of General Motors Corporation)*

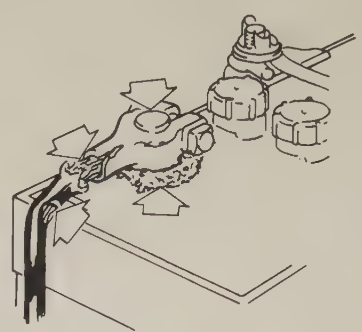


FIG. 22-2 Corroded battery cables and terminal posts.

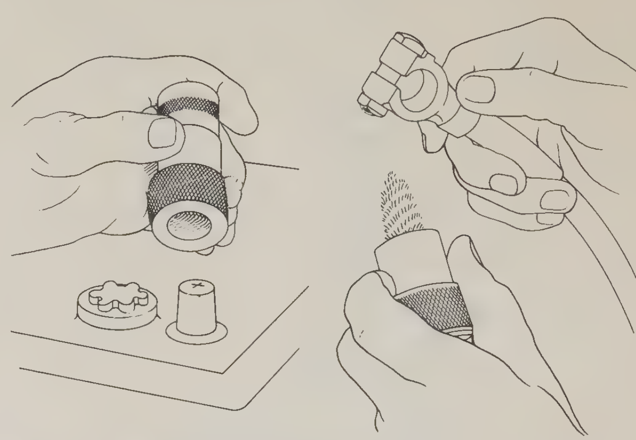


FIG. 22-3 Using a wire battery-cleaning brush to clean the battery terminal posts and cable clamps.

of water. Brush on the solution, wait until the foaming stops, and then flush off the battery top with water. If the buildup of corrosion around the terminals is heavy, detach the cables from the terminals (as explained later), and use battery-cleaning brushes, shown in Fig. 22-3, to clean the terminal posts and cable clamps. Then coat the terminals with an anticorrosion compound to retard additional corrosion.

○ 22-5 CHECKING BATTERY CONDITION There are several ways to test battery condition. The most common way is with a battery hydrometer. Other methods use testing meters. In the shop, you will be shown how to use the instruments that are available and how to tell a good battery from a bad battery. Here we cover the highlights of the tests.

○ 22-6 HYDROMETER TEST The hydrometer tests the specific gravity, or gravity, of the battery electrolyte. It has a rubber bulb at top, a glass tube, a float, and a rubber tube at the bottom (Fig. 22-4). You use it by squeezing the bulb, putting the end of the tube into the battery cell, and then releasing the bulb. This will draw electrolyte up into the glass tube. The float will float in this electrolyte. How far the stem of the float sticks out of the electrolyte tells you the battery state of charge. Take the reading at eye level, as shown in Fig. 22-4.

In making this test, do not drip electrolyte on the paint or on yourself! It will ruin the paint on the equipment, corrode metal, and eat holes in your clothes! See Cautions in ○ 22-1.

Figure 22-5 shows how to read the hydrometer. If the float sticks out to the extent that the reading on the stem is between 1.260 and 1.290, the battery is fully charged. If the reading at the electrolyte level is between 1.200 and 1.230, the battery is only half charged. If the reading is around 1.140, the battery is about run down and needs a recharge. The following table of specific-gravity readings gives a general idea of battery condition.

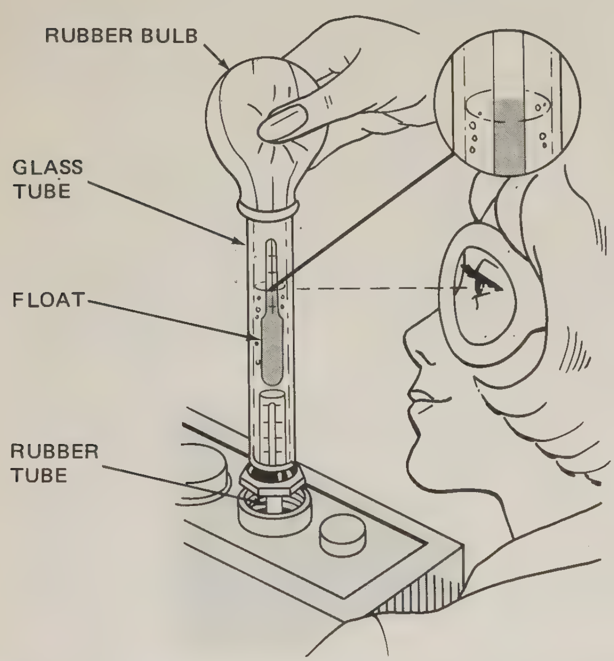


FIG. 22-4 Using a battery hydrometer to check the specific gravity of a battery cell. The reading should be taken at eye level.

- 1.265–1.299: Fully charged battery
- 1.235–1.265: Three-fourths charged
- 1.205–1.235: One-half charged
- 1.170–1.205: One-fourth charged
- 1.140–1.170: Barely operative
- 1.110–1.140: Completely discharged

If some cells test much lower than others, it means there is something wrong with the cells. There could be a cracked case that has allowed electrolyte leakage, or perhaps there has been internal damage to the plates or separators. If the variation is only a few specific-gravity points, then there probably is no major defect. But, if the low cells measure 25 to 50 points lower, then those cells are defective and the battery should be replaced.

It should be noted that some 12-volt batteries have a lower specific gravity when charged. For example, one battery is charged when it has a specific gravity of 1.270. Other batteries, for example, those used in hot climates, have a specific gravity of only 1.225 when fully charged.

The decimal point is not referred to in a discussion of specific gravity. For example, "twelve twenty-five" means 1.225 and "eleven-fifty" means 1.150.

○ 22-7 VARIATION OF SPECIFIC GRAVITY WITH TEMPERATURE Specific gravity is affected not only by the state of charge but also by temperature. As a liquid cools, it becomes thicker and gains specific gravity. As a liquid warms, it becomes thinner and loses gravity. Temperature must therefore be considered when a gravity reading is taken. A correction must be made if the temperature varies from standard. This correction involves the addition or

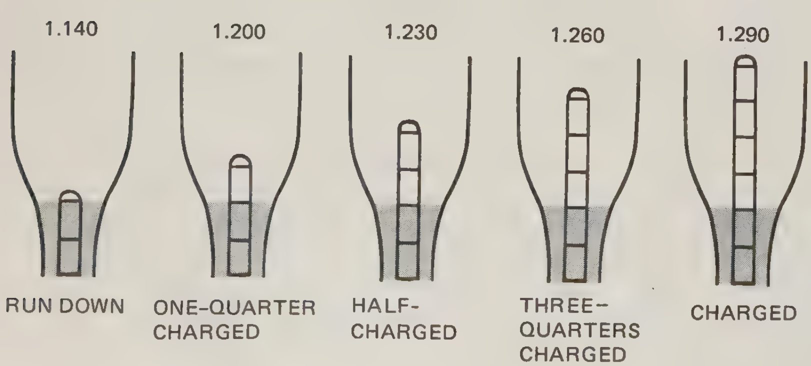


FIG. 22-5 Various specific-gravity readings. *(Delco-Remy Division of General Motors Corporation)*

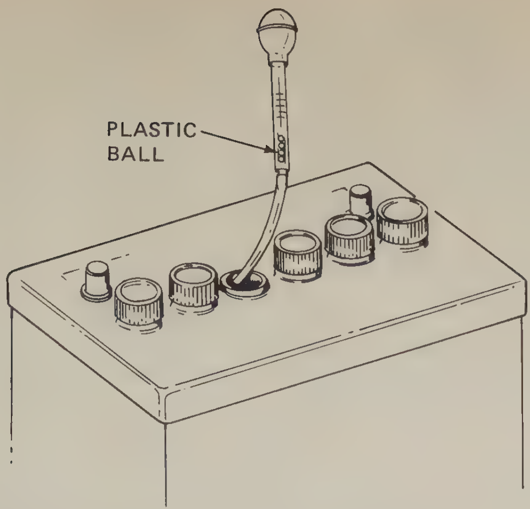


FIG. 22-6 A ball-type hydrometer that does not require temperature compensation. *(Tecumseh Products Company)*

subtraction of gravity points, according to whether the electrolyte temperature is above or below the 80°F [26.7°C] standard. The gravity of electrolyte changes about four points, or thousandths (0.004), for every 10°F [5.5°C] temperature. To make a temperature correction, four points must be subtracted for every 10°F [5.5°C] below 80°F [26.7°C].

Examples: 1.250 at 120°F. Add 0.016 (4×0.004). Corrected reading is 1.266.

1.230 at 20°F. Subtract 0.024 (6×0.004). The corrected reading is 1.206.

Another type of hydrometer is sometimes used. It is much smaller and simpler to use than the one discussed above. Basically, the small hydrometer has four small plastic balls in it, as shown in Fig. 22-6, instead of a float. When electrolyte is drawn into the tube, the condition of the cell is told by the number of balls that float. If all the balls float, the cell is fully charged. If no balls float, the cell has no charge.

○ 22-8 LOSS OF SPECIFIC GRAVITY FROM AGE As the battery ages, the electrolyte gradually loses specific gravity. This is because of the loss of active material from the plates (as the material sheds and drops into the bottom of the cells). It is also because of loss due to gassing. Over a period of two years, for example, battery electrolyte may drop to a top gravity, when the battery is fully charged, of not more than 1.250. The original top gravity, when the battery was new, may have been 1.280. Little can be done to restore gravity, since the loss is an indication of an aging battery.

○ 22-9 LOSS OF GRAVITY FROM SELF-DISCHARGE If a battery is allowed to stand idle for a long time, it will slowly self-discharge. This is brought about by internal chemical reactions between the battery materials. The higher the battery temperature is, the more rapidly self-discharge will take place. The lead sulfate that forms on the battery plates as a result of self-discharge is difficult to reconvert into active material. A battery that is badly self-discharged may be ruined.

○ 22-10 SPECIFIC GRAVITIES FOR HOT CLIMATES In hot climates, chemical activities take place more readily in the battery. It is often desirable to adjust the gravity reading to as low as 1.210 (28.5 percent acid) for a fully charged battery. This reduces the amount of self-discharge and prolongs the life of the battery. On discharge, the electrolyte may be reduced to a gravity as low as 1.075 before the battery stops delivering current. Where there is no danger of freezing, low gravities can be used.

○ 22-11 FREEZING POINT OF ELECTROLYTE The higher the specific gravity of the electrolyte, the lower the electrolyte freezing point. The battery must be kept in a sufficiently charged condition to prevent the electrolyte from freezing. Freezing usually ruins the battery. Figure 22-7 shows the freezing point of electrolyte of various specific gravities.

○ 22-12 HIGH-DISCHARGE OR CAPACITY TEST For this test, the battery voltage is measured during a high discharge. The battery should be in good condition with no obvious defects, such as a broken cover or case. Figure 22-8 shows a battery being given a high discharge while the voltage is being measured. Specifications for the amount of high discharge vary. You should always check the manufacturer's manual. Figure 22-9 outlines the recommended procedure.

○ 22-13 CADMIUM-TIP TEST This test requires a special tester. The tester has cadmium tips that are inserted into the electrolyte of adjacent cells (Fig. 22-10) after filler plugs are removed. Electrolyte must be up to the proper level. If the engine has been operated, or the battery charged, within the preceding eight hours, turn on the headlights for one minute. Then turn the headlights off. Start the test by putting the red probe into the cell that has a positive termi-

Specific gravity	Freezing temperature, degrees Fahrenheit [°C]
1.100	18 [−8]
1.160	1 [−17]
1.200	−17 [−27]
1.220	−31 [−35]
1.260	−75 [−59]
1.300	−95 [−71]

FIG. 22-7 Table showing freezing temperatures of electrolyte of various specific gravities.

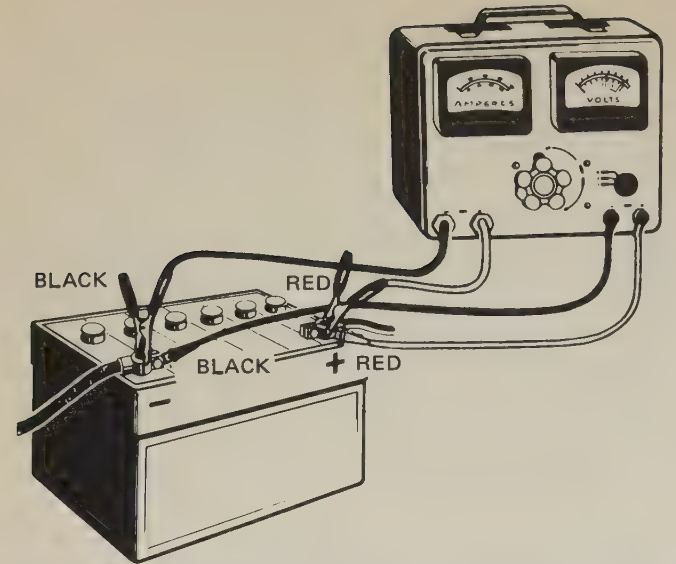


FIG. 22-8 Testing battery voltage under high discharge.

nal. Put the black probe into the next cell. Note the meter reading. Move the probes to cells 2 and 3, and so on, noting the meter readings. Compare the readings. The readings can be interpreted as follows:

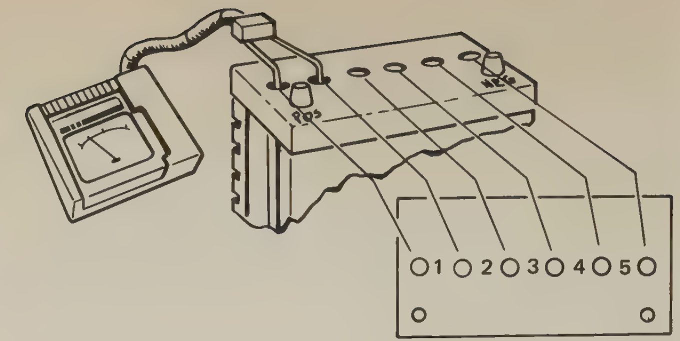


FIG. 22-10 Testing battery cells with a cadmium-tip battery-cell voltage tester.

1. If any two cells vary five scale divisions or more (top scale), the battery is at the point of failure and needs to be replaced.
2. If all cells vary less than five scale divisions and all read in the green section, the battery is charged and in good condition.
3. If all cells vary less than five scale divisions and some fall in the red section, the battery is in good condition but needs charging.

BATTERY CAPACITY TEST

ADJUST RESISTANCE UNTIL AMMETER READS 3 TIMES AMPERE-HOUR RATING OF BATTERY. HOLD FOR 15 SECONDS AND NOTE VOLTAGE.

VOLTAGE OVER 9.6

CHECK SPECIFIC GRAVITY. CHARGE BATTERY IF BELOW 1.230. OTHERWISE BATTERY IS OKAY.

VOLTAGE LESS THAN 9.6

CHECK SPECIFIC GRAVITY OF EACH CELL

LESS THAN 50 POINTS (0.050) BETWEEN CELLS

ADD WATER IF NECESSARY. CHARGE BATTERY PER CHARGING SCHEDULE AND REPEAT CAPACITY TEST.

TOTAL VOLTAGE LESS THAN 9.6

REPLACE BATTERY

TOTAL VOLTAGE MORE THAN 9.6

BATTERY IS SERVICEABLE

MORE THAN 50 POINTS (0.050) BETWEEN CELLS

REPLACE BATTERY

FIG. 22-9 Procedure for making a typical battery capacity test.

4. If any reading falls in the recharge and retest area, the battery is too low to make a good test. Recharge and retest it.

○ 22-14 BATTERY SERVICE Battery service can be divided into four parts: visual inspection, testing and trouble diagnosis, charging, and care of batteries in stock.

○ 22-15 BATTERY TESTING AND TROUBLE DIAGNOSIS Battery testing includes a check of the condition of the battery. It should also include analysis of any abnormality found, so that corrections can be made. This will prevent any repetition of the trouble. The following are various troubles and their possible causes:

1. *Overcharging.* If the battery requires a considerable amount of water, it is probably being overcharged. Too much current is probably being supplied to the battery. This is a damaging condition that overworks the active material in the battery and shortens the battery life. In addition, overcharging causes more rapid loss of water from the battery electrolyte. Unless this water is replaced frequently, the electrolyte level is likely to fall below the tops of the plates. This exposes the plates to the air and may ruin them. Also, battery overcharge causes the battery plates to crumble. Therefore, a battery subjected to severe overcharging will soon be ruined. Where severe overcharging is occurring or suspected, the charging system should be checked. It should be adjusted if necessary to prevent overcharging, as explained in Chap. 28.
2. *Undercharging.* If the battery is discharged, it should be recharged as outlined later in this chapter (unless it is an old battery approaching failure and requiring replacement). In addition, an attempt should be made to determine the reason that it is discharged. The reason could be one of the following:
   a. Charging system malfunction
   b. Defective connections in the charging circuit between the generator or alternator and the battery
   c. Excessive load demands on the battery
   d. A defective battery
   e. A battery that has been permitted to stand idle for long periods so that it has self-discharged excessively
   f. An old battery
3. *Sulfation.* The active materials in the plates are converted into lead sulfate during discharge. This lead sulfate is reconverted into active material during recharge. However, if the battery stands for long periods in a discharged condition, the lead sulfate is converted into a hard, crystalline substance. This substance is difficult to reconvert into active materials by normal charging processes. Such a battery should be charged at half the normal rate for 60 to 100 hours. Even though this long recharging period may reconvert the sulfate to active material, the battery may still remain in a damaged condition. The crystalline sulfate, as it forms, tends to break the plate grids.
4. *Cracked case.* A cracked case may result from excessively loose or tight hold-down clamps, from battery freezing, or from flying stones.
5. *Bulged cases.* Bulged cases result from tight hold-down clamps or from high temperatures.
6. *Corroded terminals and cable clamps.* This condition occurs naturally on batteries. You should be prepared to remove excessive corrosion periodically from terminals and clamps. Cable clamps should be disconnected from the terminal and the terminal posts and cables cleaned, as explained in ○ 22-4.
7. *Corroded battery holder.* Some spraying of battery electrolyte is natural as the battery is being charged. The battery holder may become corroded from the effects of the electrolyte. Such corrosion may be cleaned off, with the battery removed. Use a wire brush and common baking-soda solution.
8. *Dirty battery top.* The top of the battery may become covered with dirt and grime mixed with electrolyte sprayed from the battery. This should be cleaned off periodically as explained in ○ 22-4.
9. *Discharge to metallic hold-down.* If the hold-down clamps are of the uncovered metal type, a slow discharge may occur from the insulated terminals to the hold-down clamp. This may occur with a dirty battery top, across which current can leak. The remedy is to keep the battery top clean and dry.

○ 22-16 REMOVING AND REPLACING A BATTERY To remove a battery from any equipment, such as a car, motorcycle, or garden tractor, first take off the clamp from the grounded-battery-terminal cable. This prevents accidental grounding of the insulated terminal when it is disconnected. To remove a nut-and-bolt type of cable (Fig. 22-11), loosen the clamp nut about 3/8 inch [10 mm]. Use a box wrench or battery pliers (Fig. 22-12). Do not use a screwdriver or bar to pry on a clamp. This could damage the battery cell or cover. Then use a battery-clamp puller to pull the cable from the battery terminal (Fig. 22-12). To detach

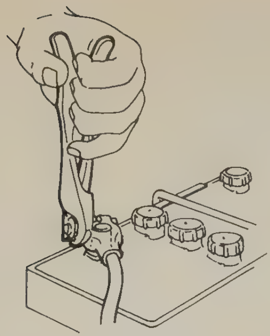


FIG. 22-11 Using battery-nut pliers to loosen a nut-and-bolt type of battery cable. *(United Delco Division of General Motors Corporation)*

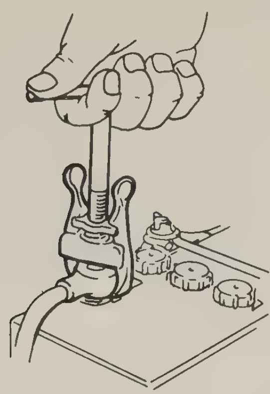


FIG. 22-12 Using a battery-clamp puller to pull the cable from a battery terminal. *(United Delco Division of General Motors Corporation)*

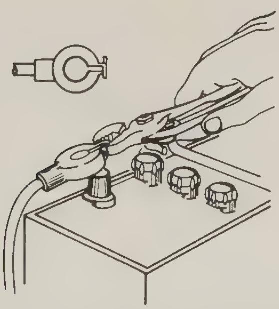


FIG. 22-13 Using pliers to loosen a spring-ring type of cable clamp from a battery terminal. *(United Delco Division of General Motors Corporation)*

the spring-ring type of clamp, squeeze the ends of the rings apart with Channellock pliers (Fig. 22-13).

After the grounded cable is disconnected, disconnect the insulated-terminal cable. Clean both battery terminals and cable clamps with special tools (Fig. 22-3). Loosen the battery hold-downs, and take out the battery. When installing a battery, do not reverse the terminal connections. (Some engines have the negative terminal grounded, others the positive terminal.) Reconnect the insulated-terminal cable. Apply corrosion inhibitor to clamps and terminals. Install and tighten the hold-down. Avoid overtightening.

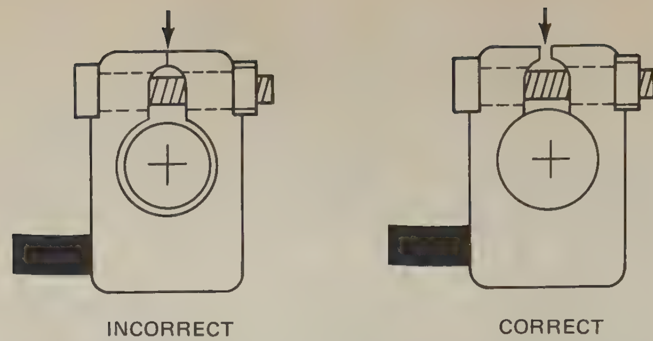


FIG. 22-14 If there is no gap between the jaws of the clamp (left), the clamp is probably loose on the terminal post.

CAUTION: Make sure the cable clamps are tight and make good connections with the terminal posts. If the jaws of the clamp come together as shown at the left in Fig. 22-14, chances are the clamp is not tight on the post. This could mean starting trouble. Correct the condition by disconnecting the clamp from the post. Shave the clamp jaws with a file so you get a gap as shown to the right (Fig. 22-14) when the clamp is installed.

○ 22-17 BATTERY ADDITIVES *Dopes* is a good name for certain chemical compounds that are supposed to restore a battery to a charged condition. Such chemicals should never be added to the battery. Their use may void the battery guarantee and cause battery failure.

○ 22-18 BATTERY-CHARGING METHODS Two methods of charging a battery now are used. These are the constant-current method and the constant-voltage method. Since most localities have alternating current only, the battery-charging devices must convert this alternating current (ac) to direct current (dc) and supply it to the battery at a constant current or voltage.

CAUTION: The gases released by batteries are highly explosive. Therefore, battery-charging areas should be well ventilated.

You need charging lead adapters, as shown in Fig. 22-15, to connect to the types of terminals set in the side rather than in the top of the battery. Batteries with recessed screw-type terminals in the top, as shown in Fig. 22-16, also may require special bolts or adapters.

○ 22-19 CONSTANT-CURRENT CHARGING The constant-current charger usually employs a rectifier, which may be a gas-filled bulb or a series of copper oxide or other chemical disks. In ac, the current (or electron flow) moves first one way and then the other. The rectifier permits the current to flow one way only.

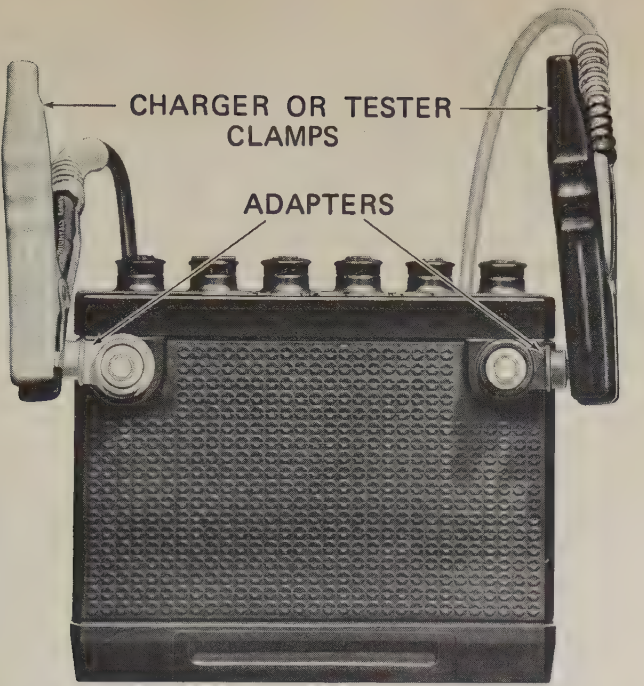


FIG. 22-15 Charging lead adapters for side-terminal batteries. *(Chevrolet Motor Division of General Motors Corporation)*

Current enters the rectifier as ac and leaves as dc. Some form of rheostat, or variable resistor, is usually incorporated in the charging system. This allows the amount of current to be adjusted to the value recommended by the battery manufacturer.

Small batteries, such as those used in motorcycles, must be charged at a very low rate. Honda, for example, recommends charging some small batteries at 1/2 amp and no more.

○ 22-20 CONSTANT-VOLTAGE CHARGING The constant-voltage charger depends on the fact that as a battery approaches charge, its terminal voltage increases (current input remaining constant). The charger usually has a 7.5-volt rating for 6-volt batteries or a 15-volt rating for 12-volt batteries. When a discharged battery is connected to the charger, a high charging current will flow into the battery. As it approaches a charged condition, the battery's terminal voltage increases and the battery's opposition to the charging current increases. By the time the battery reaches a fully charged state, only a very small charge will enter it. The charging current tapers off as the battery approaches a charged condition. This is the principle of self-regulation used in many slow chargers.

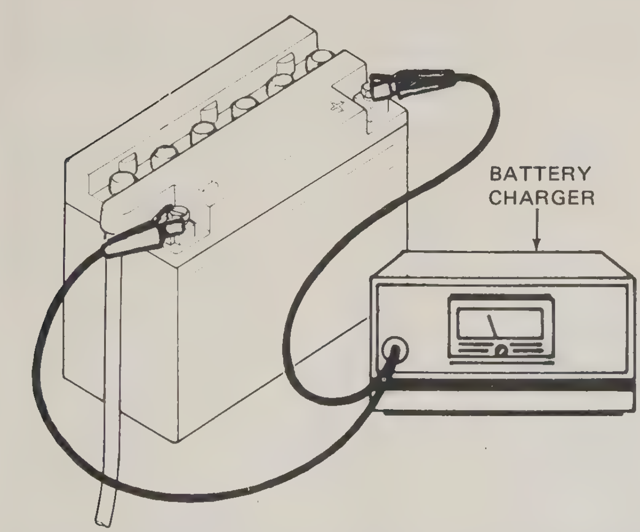


FIG. 22-16 Motorcycle batteries such as shown here may require adapters to make connections to the terminals. *(Honda Motor Company, Ltd.)*

○ 22-21 QUICK CHARGERS Quick chargers, such as the one shown in Fig. 22-17, charge the battery at a very high rate (as much as 100 amps) for a short time—30 to 45 minutes. The battery is brought to a fair state of charge before the battery temperature increases excessively. The quick-charger method does not seem to harm batteries that are not exposed to excessive temperatures. However, high charging rates combined with battery-electrolyte temperatures above 125°F [51.7°C] are very damaging to a battery.

Do not charge small motorcycle-type batteries by the quick-charge method. Also, a battery with discolored electrolyte (from cycling) or with gravity readings of more than 25 points apart should not be quick-charged. Likewise, a badly sulfated battery should not be quick-charged. Such batteries may be near failure, but they may give additional service if slow-charged. However, quick charging may damage them further. During quick charging, check the color of the electrolyte. Stop charging if the electrolyte becomes discolored as a result of the stirring up of washed-out material. Cell voltages should be checked every few minutes. Charging should be stopped if cell voltages vary more than 0.2 volt.

When quick-charging a battery in a vehicle, be sure to disconnect the battery ground strap to protect the electrical system from damage due to high voltage.

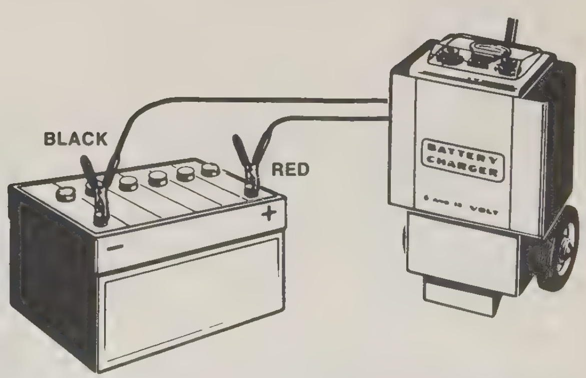


FIG. 22-17 Quick-charging an automobile battery. *(Chrysler Corporation)*

○ 22-22 CHARGING SULFATED BATTERIES When a battery has been allowed to stand for some time without charging, its plates may have become sulfated to such an extent that it will not take a charge in a normal manner. In fact, the battery may be completely ruined. However, an attempt to save such a battery may be worthwhile, especially if the battery is not too old. Put the battery on charge at half the normal charging rate for 60 to 100 hours to see whether the sulfation can be broken down so that the battery will take a charge.

○ 22-23 CARE OF BATTERIES IN STOCK Wet batteries (or batteries with electrolyte in them) are perishable. They are subject to self-discharge. If allowed to stand idle for too long a time, they can become completely ruined. To prevent this, batteries in stock should be recharged at 30-day intervals. Also, they should not be stacked on top of each other without some means of individual support. The weight of one battery is enough to collapse the plate assemblies and cause short circuits.

○ 22-24 STARTING WITH A BOOSTER BATTERY The following procedure applies to automobiles and to small-engine installations and motorcycles. The general principles apply to all installations where you must use a second, or booster, battery to start an engine. If the battery is too low to start the engine, another battery must be connected. This other battery, called a booster battery, will furnish the current the starting motor needs to start the engine. You should observe certain precautions when using a booster battery. Otherwise, you can damage the electrical equipment. If you connect the booster battery backwards, one of the batteries could explode from the high discharge current taken from it. Here is the recommended procedure for a negative-ground battery. You will need two jumper cables, as shown in Fig. 22-18.

1. Remove the vent caps from both batteries. Cover the holes with cloths to prevent splashing of the electrolyte in case of explosion.
2. Shield your eyes.
3. Do not allow the two vehicles to touch each other.
4. Make sure all electrical equipment except the ignition is turned off on the engine you are trying to start.
5. Connect the end of one jumper cable to the positive (+) terminal of the booster battery. Connect the other end of this cable to the positive (+) terminal of the dead battery.
6. Connect the other end of the second cable to the negative (−) terminal of the booster battery.
7. Connect one end of the second cable to the engine block of the car you are trying to start. Do not connect it to the negative (−) terminal of the vehicle battery! This could damage electrical equipment or cause a battery to explode. Do not lean over the battery while you are making this connection!
8. Now start the vehicle containing the booster battery. Then start the vehicle containing the low battery. After the disabled vehicle is started, disconnect the booster by first disconnecting the cable from the engine block. Then disconnect the other end of this (the negative) cable. Finally, disconnect the positive cable.

Never operate the starting motor for more than 30 seconds at a time. Pause for a few minutes to allow it to cool off. Then try it again. You can overheat and ruin a starting motor by using it for too long.

REVIEW QUESTIONS

1. What should you do if you get battery acid on your skin? In your eye?
2. Why is it dangerous to bring an open flame near a battery that is being charged?
3. How do you check the electrolyte level in batteries?

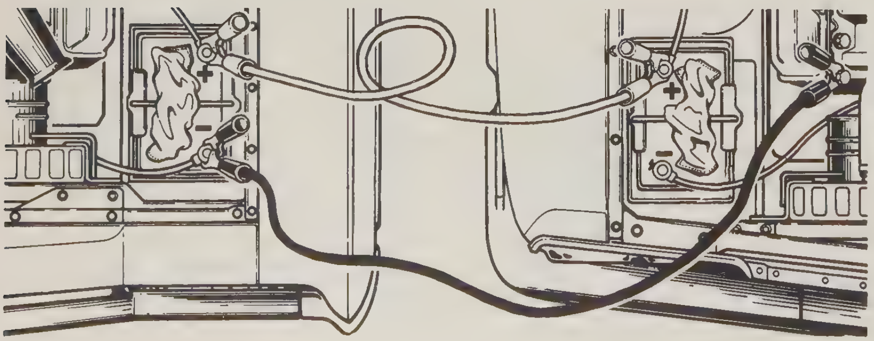


FIG. 22-18 Connections between the jumper battery and the dead battery for starting a car with a dead battery.

4. What is the Delco Eye? What is its purpose?
5. Explain how to clean corrosion off the top of a battery.
6. Explain how to use an hydrometer to test a battery.
7. Explain how to perform the cadmium-tip test on a battery.
8. Which will freeze more easily, a fully charged battery or a half-charged battery? Why?
9. Why will overcharging a battery damage it?

SELF PROJECTS

1. Make a list of the six steps in battery maintenance and file it in your notebook.
2. Write down—so you will be sure to remember it—what you should do if you get electrolyte on your skin or in your eyes. Knowing what to do could save you from a severe burn or the loss of your eyesight.

Chapter 23

Starting Systems for Small Engines

After studying this chapter, you should be able to:

1. List the types of starters used on small engines
2. Explain the operation of the various types of mechanical starters
3. Describe the construction and operation of starting motors
4. Explain the purpose of the overrunning clutch and how it works
5. Discuss the purpose of the safety interlock
6. Describe the construction and operation of a starter-generator

MECHANICAL STARTERS

○ 23-1 TYPES OF STARTERS Both mechanical and electric starters are used on small engines. The mechanical starters do not use a motor as do electric starters. Mechanical starters are usually used on small engines when weight, cost, or size must be limited. Mechanical starters are generally classed as rope-wind, rope-rewind, windup, and kick-lever types. Electric starters provide the convenience and quick power of motor starting. Although normally used with larger engines, electric starters are being used more and more on small engines. Electric starters are generally classified according to the power source used for operation. One type is operated by connecting the starter motor to 120-volt house power. The other type uses a regular 6- or 12-volt automobile-type battery. Now, let us see how various starters operate.

○ 23-2 ROPE-WIND MECHANICAL STARTERS The engine which is equipped for rope-wind starting has a pulley attached to the crankshaft. The flange of the pulley is slotted, as shown in Fig. 23-1. The starting rope has a knot in one end and a grip handle on the other. To use the rope, you hook the knot end into the flange slot. Then you wind the rope around the pulley, adjust the choke, make sure the ignition is on, and give the rope a strong pull. This spins the crankshaft to start the engine. It usually takes more than one windup-and-pull operation to get the engine started.

○ 23-3 ROPE-REWIND MECHANICAL STARTERS To avoid having to rewind the rope each time you attempt to start, manufacturers introduced the rope-rewind starter. This starter has a rope permanently connected and includes a recoil spring that rewinds the rope on the pulley after each starting attempt. Figure 23-2 shows the basic parts of the rope-rewind

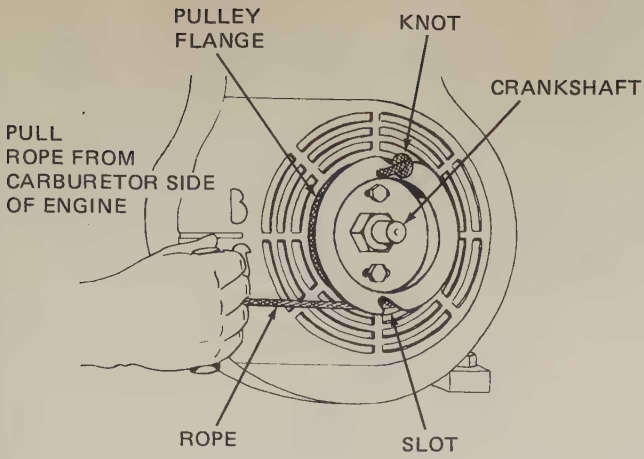


FIG. 23-1 The rope-wind starter is the simplest of all small-engine starters. You wind the rope on the pulley and pull it to spin the engine crankshaft. *(Briggs & Stratton Corporation)*

starter. Figure 23-3 shows how the rope is pulled out for starting the engine.

Let us look at the way the rope-rewind starter works. When you pull the rope, the starter pulley is turned. Centrifugal force from movement of the pulley causes the pawls to fly out and lock the pulley to the crankshaft so that it rotates as the rope is pulled out. At the same time, the recoil spring is being wound up. Note that the inside end of this spring is attached to the pulley. The outside end of the spring is attached to the starter housing. Now, after you have pulled the rope all the way out and then released it, the spring has enough tension in it to spin the pulley back in the opposite direction. This rewinds the rope on the pulley. Rewinding takes place whether or not the engine has started. On the rewind cycle, the pawls are ineffective because they do not catch in the teeth on the inside of the crankshaft adapter. At the end of the rewind cycle, the pawls are

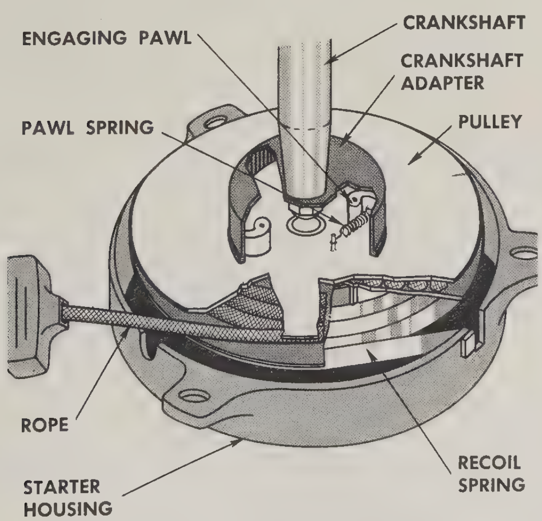


FIG. 23-2 A partially cutaway view of a typical rope-rewind starter.

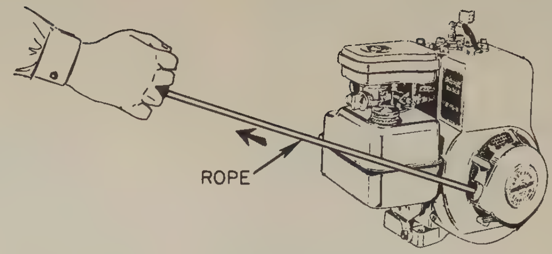


FIG. 23-3 How to use the rope-rewind starter. You pull it out to crank the engine. Then you release the pull on the handle and allow the rope to rewind on the pulley.

retracted by the small attached spring. The starter is then ready for another starting attempt.

○ 23-4 WINDUP MECHANICAL STARTERS

The windup starter is designed to reduce the amount of effort required to start a small engine. With the rope-wind and rope-rewind starters, you must exert a strong pull to spin the crankshaft. The windup starter requires much less effort: you simply wind up a spring and then release it. When the spring unwinds, it spins the crankshaft. There are several designs of the windup starter, but each operates in the same manner. Figure 23-4 shows how to use the windup starter.

First, you set the release lever so it will hold the spring on windup. Next, you swing the crank handle out and rotate it to wind up the spring. Some models lock the spring when the crank handle is returned to the running position. The release lever is then moved to allow the spring to unwind and crank the engine.

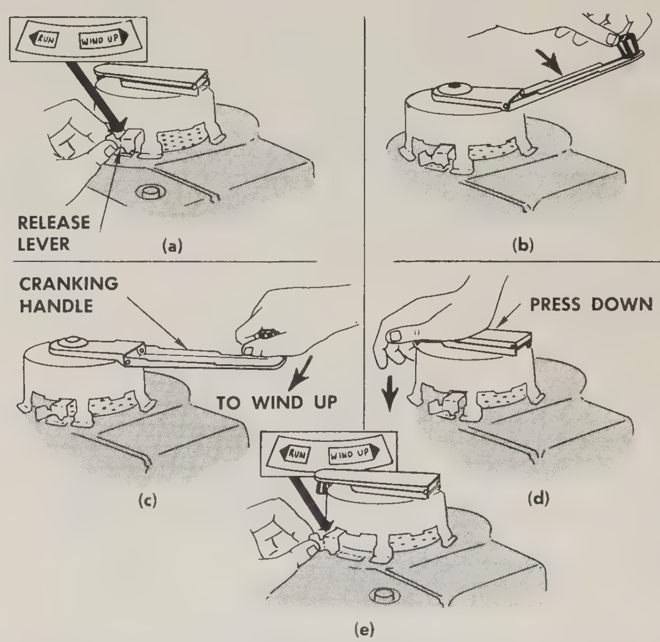


FIG. 23-4 Here are the steps in using a windup starter: *(a)* Lock the spring by moving the control lever to WINDUP. *(b)* Open the crank handle. *(c)* Wind up the recoil spring. *(d)* Fold the handle. *(e)* Release the spring by moving the control lever to RUN.

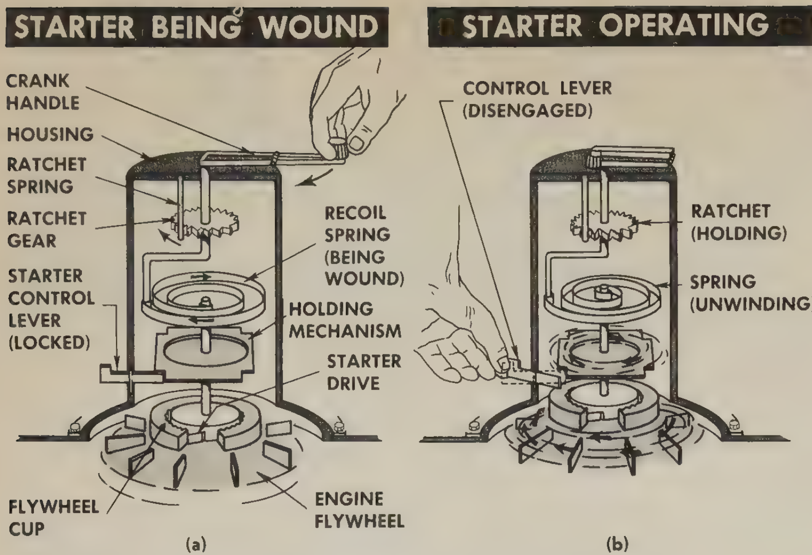


FIG. 23-5 This shows schematically how the windup starter works. Parts are shown separated so their relationship can be seen. In *(a)*, the recoil spring is being wound up. The control lever locks the holding mechanism. In *(b)*, the control lever is pushed to unlock the holding mechanism, allowing the spring to unwind and crank the engine.

On some models, the spring is automatically released when the crank handle is returned to the running position.

Figure 23-5 shows how a typical windup starter works. It includes a crank with a rachet and a second crank attached to one end of a spring. The other end of the spring is attached to a shaft that is part of the spring-holding mechanism. The shaft lower end is attached to the starter drive. The starter drive has a dog-and-rachet arrangement inside the flywheel cup. With the starter control lever set, the holding mechanism is locked in place to hold the inner end of the spring. When the crank handle is turned, the rachet gear and crank wind up the spring. The rachet spring at the top prevents the spring from unwinding. When the spring is completely wound up, the control lever is released so that the spring starts to unwind from the inside out. This engages the rachets or starter dogs inside the flywheel cup so that the flywheel is rotated to crank the engine.

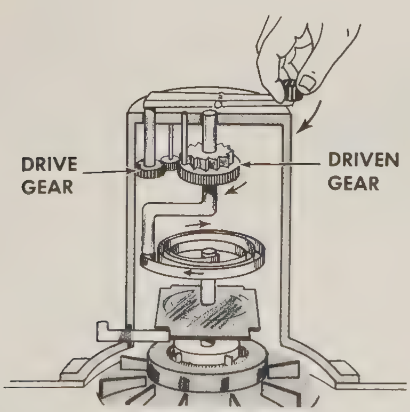


FIG. 23-6 Some windup starters have a gear reduction which makes it easier to turn the crank, although the crank must be turned more times to wind up the recoil spring.

Some designs include a reduction-gear arrangement which makes it easier to wind up the spring, as shown in Fig. 23-6. Although it requires less effort to operate the crank, the crank has to be turned more times to wind up the spring.

Typical windup starters are shown in Fig. 23-7. At the top of the illustration the major parts are shown as they would appear when removed from the engine. The lower part shows a different windup-starter model disassembled.

○ 23-5 MECHANICAL KICK STARTERS

The kick starter uses leg power for its operation and is a popular starter found on minibikes and motorcycles. All kick starters operate in a similar manner. Figure 23-8 shows the gear train for one starter model. When the kick pedal is kicked down by means of leg power, the rotary motion is carried through the gear train to the engine crankshaft, causing it to spin. When the pedal is released, a heavy spring returns it to the former raised position. It may take several kicks to start a cold engine. The gear train in Fig. 23-8 has a considerable increase in gear ratio from the kick-shaft gear to the crankshaft primary pinion gear. This increases the crankshaft revolution rate so that it spins rapidly when the kick-shaft gear rotates. Once the engine is running, the starter is disengaged from the crankshaft. The one-way starter motion is achieved in different ways, depending on the design.

One kick-starter design is shown in Fig. 23-9, to illustrate how one-way starter motion is possible. The kick-shaft gear is free to rotate on the kick shaft. A ratchet wheel (also called a gear) can move back and forth on splines of the kick shaft. When the engine is running, the arm on the ratchet wheel is resting behind the stopper guide. This holds the ratchet wheel away from the kick-shaft gear. However, when the

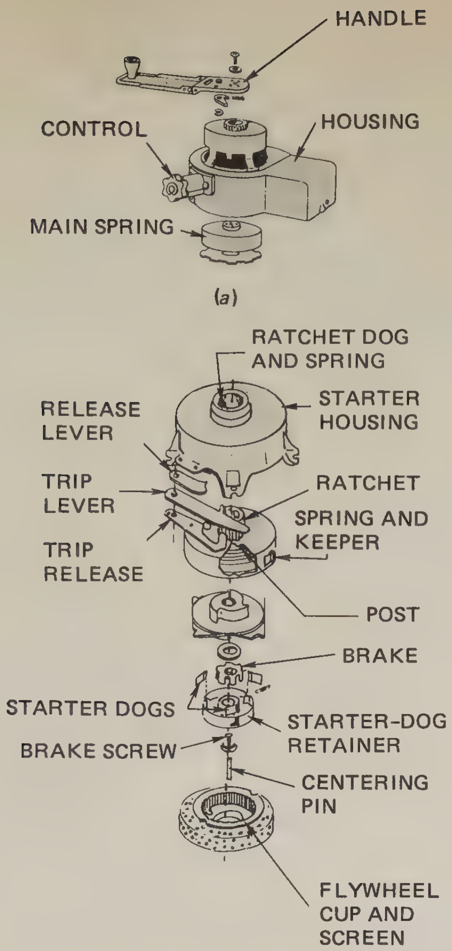


FIG. 23-7 Assembled and disassembled views of windup starters. In *(a)*, the type shown must be disassembled from the handle end. In *(b)*, the type shown must be disassembled by first removing the drive mechanism.

kick pedal is pushed down, the kick shaft turns, forcing the ratchet wheel to turn. The arm on the ratchet wheel moves out from behind the stopper guide. The spring-back of the ratchet wheel now forces the ratchet forward so that the ratchet teeth mesh to engage the kick-shaft gear. Further movement of the

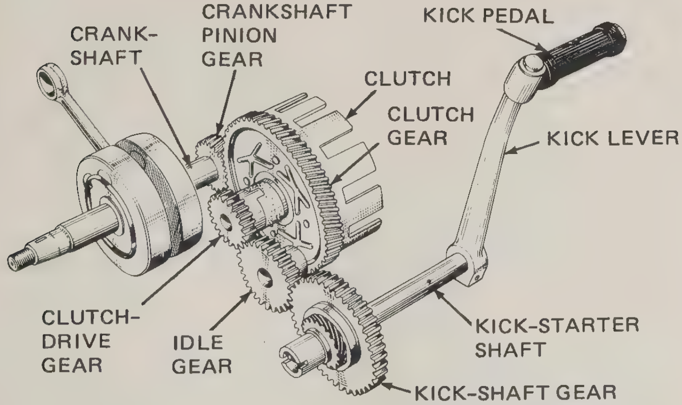


FIG. 23-8 Gear train from kick lever to the gear on the crankshaft. *(Suzuki Motor Company)*

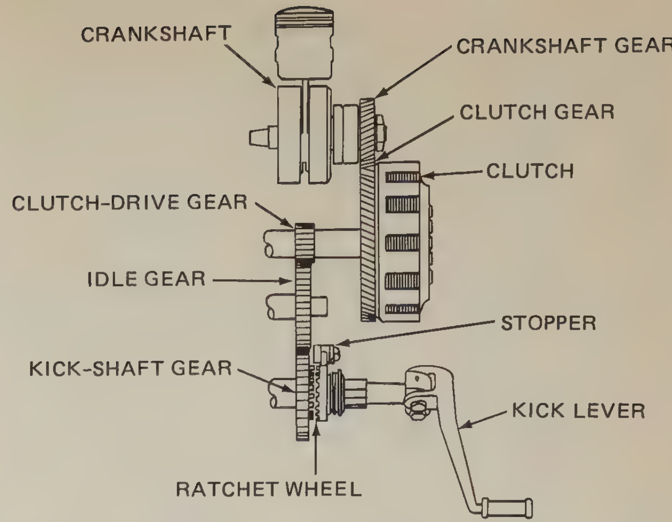


FIG. 23-9 Gear train from kick lever to the crankshaft for a three-cylinder engine. *(Suzuki Motor Company)*

kick pedal forces the kick-shaft gear to turn. This transmits motion through the gears, causing the crankshaft to spin.

As the engine starts, it backdrives the kick-shaft gear. However, the ratchet is a one-way device, and so the kick-shaft gear spins without driving the ratchet wheels. The ratchet teeth are disengaged, and no motion is transmitted to the kick-starter shaft.

ELECTRIC STARTERS

○ 23-6 ELECTRIC MOTORS In the electric starter, an electric motor provides the power to spin the engine crankshaft and start the engine. The battery furnishes the electricity to operate the motor. (Some electric starters for small engines use 120-volt house current.) Taking electricity out of the battery runs it down. This means that there must be a charging system to put electricity back into the battery. The electrical system for an engine or equipment using electric starting is considerably more complicated than the simple mechanical-starting arrangement.

Some small engines use a 12-volt starter-generator, as shown in Fig. 23-10, which cranks the engine

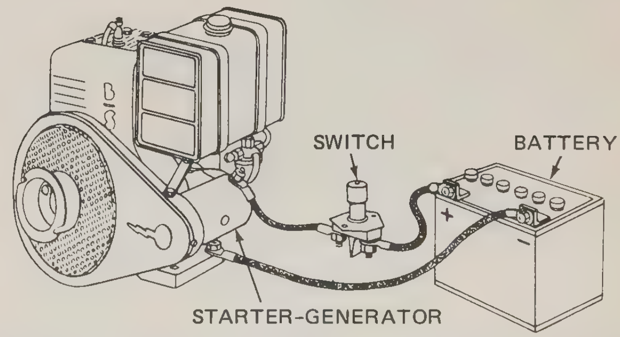


FIG. 23-10 Battery starter system. This system includes an electric starter which is also a generator to recharge the battery. *(Briggs & Stratton Corporation)*

for starting. It also remains connected to the engine and battery. Then the starter-generator is driven by the engine after it starts to produce an electric current. This electric current charges the battery and also handles any electrical loads that might be turned on, such as lights. We discuss this system later in the chapter.

○ 23-7 BASIC MOTOR PRINCIPLES Most electric starting motors are low-voltage direct-current motors, taking their electric current from a storage battery (Fig. 23-10). This type of starting motor is a special high-capacity heavily-constructed electric motor. It is designed to produce a high horsepower for its size for short periods of time. It is not the type of motor that can be operated continuously. The unit is also called a starter, a starter motor, and a cranking motor. It works on the same basic motor principles that apply to all electric motors. The job of the starting motor is to convert electrical energy from the battery into mechanical energy that spins the crankshaft.

When current moves through a conductor, a magnetic field builds up around that conductor. If the conductor is in a magnetic field, as from a horseshoe magnet, force is exerted on the conductor. Figure 23-11 illustrates the conductor in a magnetic field. Figure 23-12 shows the conductor in end view, with the resulting magnetic field indicated. The cross in the center of the conductor indicates that the current is flowing away from the reader. This causes the magnetic field due to the current flow to circle the conductor in a counterclockwise direction. The circular magnetic field to the left of the conductor is in the same direction as the straight-line magnetic field from the magnet. To the right of the conductor, it is in the opposite direction. This weakens the magnetic field to the right of the conductor. It strengthens the magnetic field to the left of the conductor. Therefore, the resulting magnetic field distorts around the conductor, as shown in Fig. 23-12.

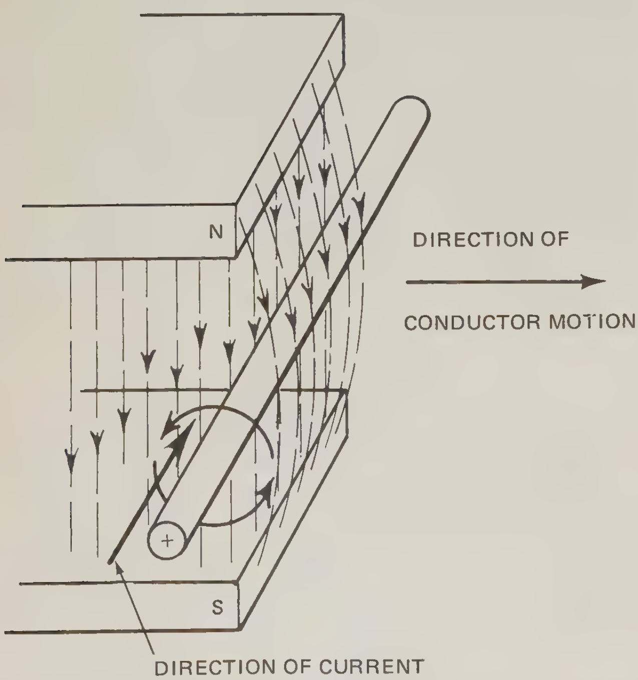


FIG. 23-11 Conductor moved in the magnetic field of a magnet. The direction of current flow and the encircling magnetic field around the conductor are shown by arrows.

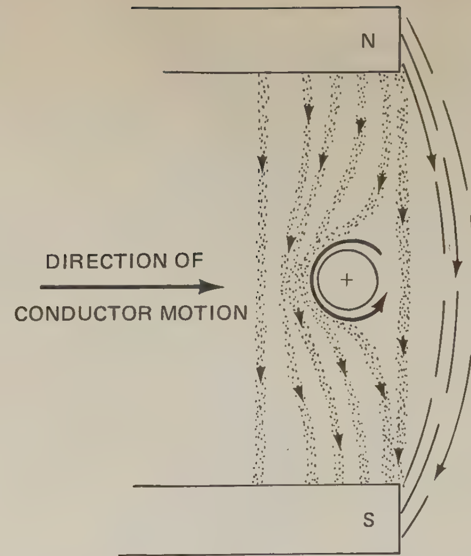


FIG. 23-12 End view of the conductor shown in Fig. 23-11.

Magnetic lines of force tend to shorten up to a minimum length. The bent lines of force in the magnetic-field pattern in Fig. 23-12 tend to straighten out. As they do, they exert a push to the right on the conductor. The more current is flowing, the more the lines of force will be distorted around the conductor—and the stronger will be the push. Increasing the straight-line magnetic field has a similar effect.

○ 23-8 MOTOR CONSTRUCTION Suppose we bend the conductor into a U shape and connect the two ends to the two halves of a split copper ring. We now have the elements of an electric motor (Fig. 23-13). Stationary brushes, connected to a battery and

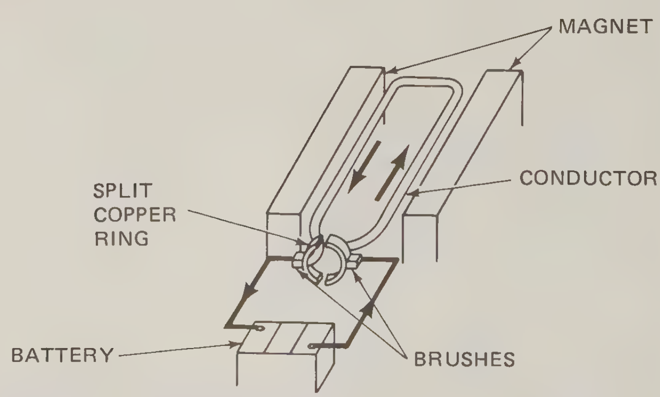


FIG. 23-13 Simple electric motor with a two-segment commutator.

resting on the split ring, and two poles of a magnet complete the motor. The brushes are carbon blocks that form sliding contacts with the commutator. The U-shaped conductor loop and the split ring (which is called the commutator) are able to rotate together. Current flows from the battery through the right-hand brush and segment of the commutator. Then it flows, through the conductor and left-hand segment of the commutator and brush, back to the battery, as shown in Fig. 23-13. This causes the left-hand part of the conductor to be pushed upward and the right-hand part to be pushed downward (Fig. 23-13). Therefore, the loop rotates in a clockwise direction. As the two sides of the loop reverse positions, the direction of the current flow through the two sides reverses. The magnetic force continues to rotate the loop clockwise.

The starting motor must use more than one loop to develop enough power. Actually, many loops or conductors are used, as shown in Fig. 23-14, which illustrates a starting-motor armature and field assembly. The ends of the conductors in the armature are connected to the commutator segments.

High magnetic-field strength is needed for powerful starting-motor actions. The natural magnetic strength of the magnetic poles is aided by an electromagnet formed by the field windings. Current flows through the field windings in such a direction as to increase the magnetic field between the two poles. Figure 23-15 is a simple wiring diagram of a starting motor. Current enters the motor and passes through the two field windings, then through the armature, and back to the battery. If the battery connections were reversed, the current would flow through the armature first, as shown in Fig. 23-16. This is a schematic drawing of a simple motor. This type of motor is called a *series-wound*, or *series*, motor. The armature and field windings are connected in series.

The wiring diagram in Fig. 23-15 is a two-pole two-brush starting motor. Many starting motors have four brushes and four poles. Some also have one or two parallel or shunt windings (and are called series-shunt or compound starting motors). The shunt windings prevent overspeeding (Fig. 23-17).

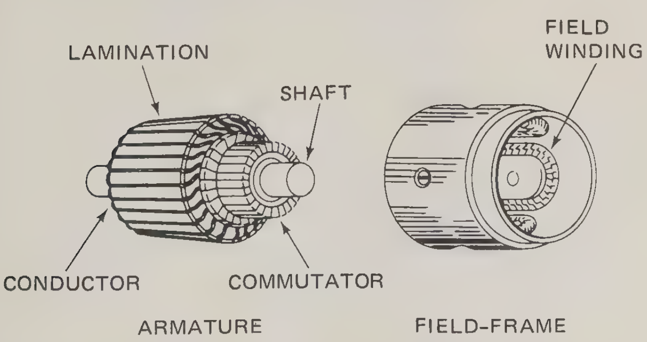


FIG. 23-14 Two major parts of a starting motor: the armature and the field assembly. *(Delco-Remy Division of General Motors Corporation)*

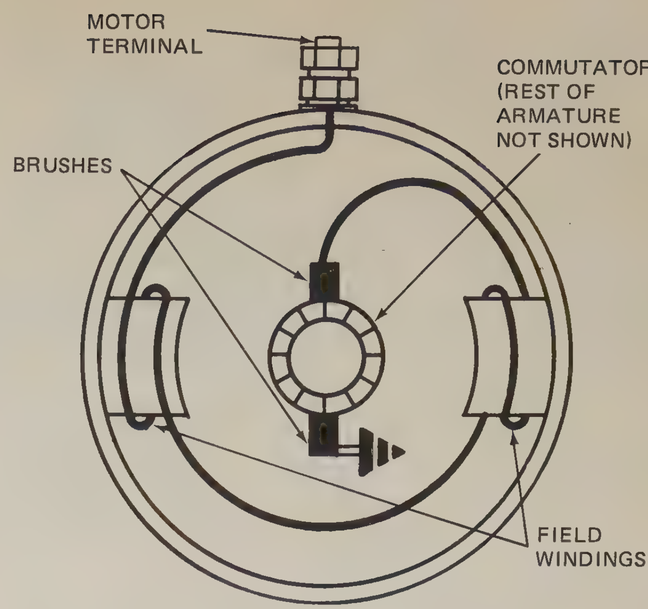


FIG. 23-15 Wiring diagram for a starting motor.

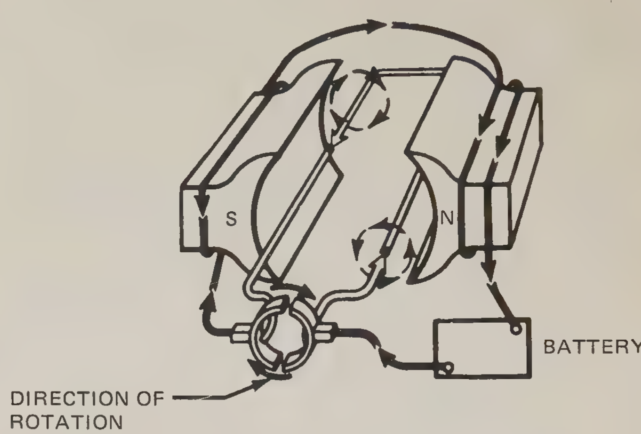


FIG. 23-16 Schematic drawing of a starting motor. The heavy arrows show the direction of current flow. The light circular arrows show the direction of the magnetic field around the conductors. Compare this with Fig. 23-13.

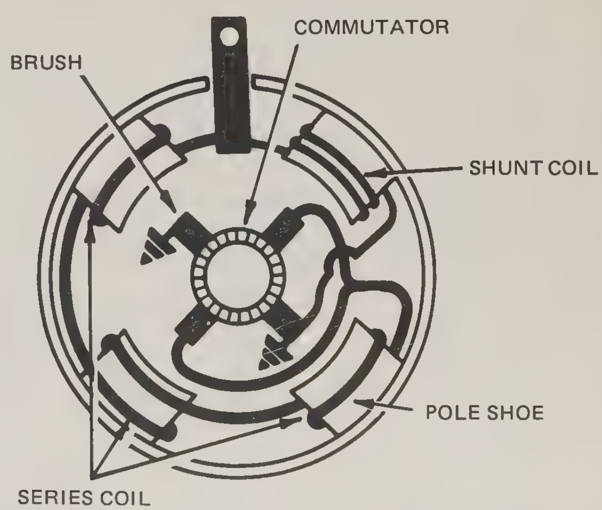


FIG. 23-17 Wiring diagram for a four-pole series-shunt, or compound, starting motor. *(Delco-Remy Division of General Motors Corporation)*

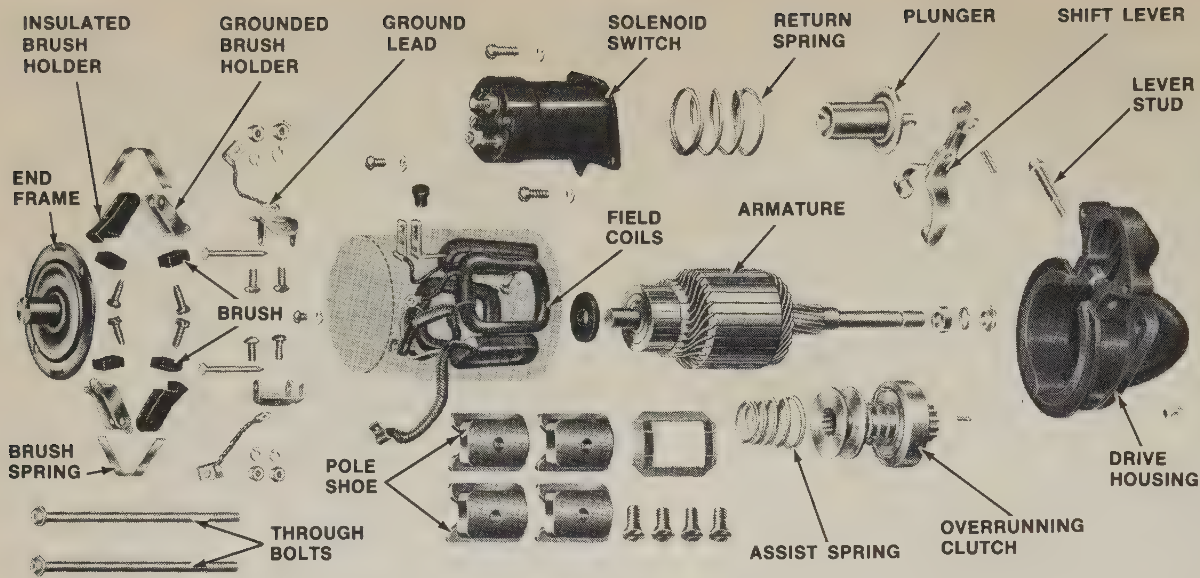


FIG. 23-18 Disassembled view of a starting motor. *(Delco-Remy Division of General Motors Corporation)*

A typical starting motor, with the main parts disassembled, is shown in Fig. 23-18. The motor consists of the following:

1. The commutator end head, holding the brushes
2. The field frame, into which the field windings are assembled around iron pole shoes
3. The drive housing, which houses the drive assembly and supports the motor on the engine flywheel housing
4. The armature
5. The drive assembly

Some starting motors also have a solenoid that operates the shift lever (○ 23-11).

○ 23-9 DRIVE ARRANGEMENT The drive assembly contains a small pinion that, in operation, meshes with teeth cut in the flywheel (Fig. 23-19). This provides gear reduction, so that the armature must rotate about fifteen times to cause the flywheel to rotate once. The armature may revolve about 2000 to 3000 rpm (revolutions per minute) when the starting motor is operated. This causes the flywheel to spin at speeds as high as 300 rpm. This is ample speed for starting the engine.

After the engine starts, it may increase in speed to 3000 rpm or more. If the starting-motor drive pinion remained in mesh with the flywheel, it would be spun at 45,000 rpm because of the 15 : 1 gear ratio. This means that the armature would be spun at this terrific speed. Centrifugal force would cause the conductors and commutator segments to be thrown out of the armature, ruining it. To prevent such damage, automatic meshing and demeshing devices are used. For automobile and battery-powered small-engine starters, there are two general types, inertia and overrunning clutch, described below.

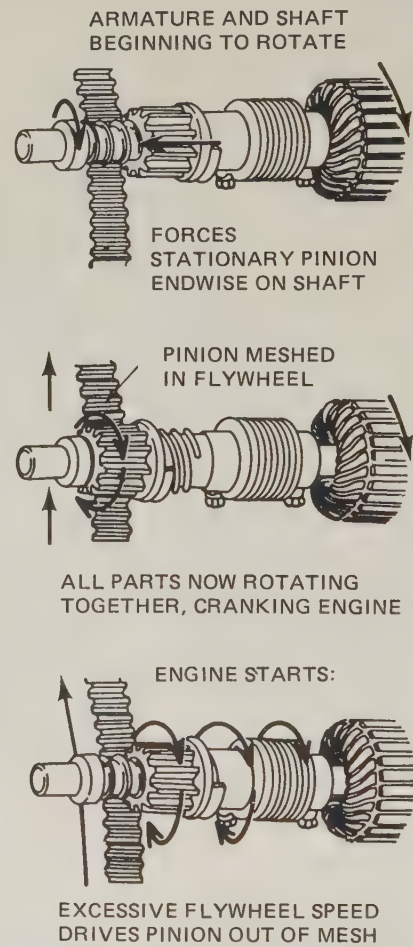


FIG. 23-19 Operation of a Bendix drive. *(Delco-Remy Division of General Motors Corporation)*

○ 23-10 INERTIA DRIVE The inertia drive depends on the drive pinion to produce meshing. Inertia is the property that all things resist any change in motion.

When the drive pinion is not rotating, it resists any force that attempts to set it into motion. There are several types of inertia drive.

In the Bendix drive (Fig. 23-19), the drive pinion is mounted loosely on a sleeve. The sleeve has screw threads matching internal threads in the pinion. When the starting motor is at rest, the drive pinion is not meshed with the flywheel teeth. As the starting motor switch is closed, the armature begins to rotate. This causes the sleeve to rotate also, since it is fastened to the armature shaft through the heavy spiral Bendix spring. Inertia prevents the pinion from instantly picking up speed with the sleeve. Therefore, the sleeve turns within the pinion, just as a screw would turn in a nut held stationary. This forces the pinion endways along the sleeve so that the pinion goes into mesh with the flywheel teeth. As the pinion reaches the pinion stop, the endways movement stops. The pinion must now turn with the armature, causing the engine to be cranked. The spiral spring takes up the shock of meshing.

After the engine starts and increases in speed, the flywheel rotates the drive pinion faster than the armature is turning. This causes the pinion to be spun back out of mesh from the flywheel. The pinion turns backwards on the sleeve. The screw threads on the pinion and sleeve cause the pinion to be backed out of mesh with the flywheel.

The rubber-compression type of drive (Fig. 23-20) is similar to the compression-spring type. It is used on starting motors for outboard engines and on other small engines. In this starting motor, a rubber cushion takes up the shock of meshing as the drive pinion meshes with the flywheel.

○ 23-11 OVERRUNNING-CLUTCH DRIVE

More positive meshing and demeshing of the pinion and flywheel teeth is provided by the overrunning clutch drive. The overrunning clutch uses a shift lever (Fig. 23-18) to slide the pinion along the armature shaft and into, or out of, mesh with the flywheel teeth. The overrunning clutch is designed to transmit driving torque from the starting-motor armature to the flywheel. Then the clutch permits the pinion to overrun (run faster than) the armature after the engine has started.

The overrunning-clutch drive (Fig. 23-21) consists of a shell-and-sleeve assembly, which is splined internally to match splines on the armature shaft. A pinion-and-collar assembly fits loosely into the shell. The collar makes contact with four hardened-steel rollers, which are assembled into notches cut from the shell. These notches taper slightly inward. There is less room in the end away from the rollers than in the end where the rollers are shown. Spring-loaded plungers rest against the rollers.

The shift lever, which causes the clutch assembly to move endways along the armature shaft, is oper-

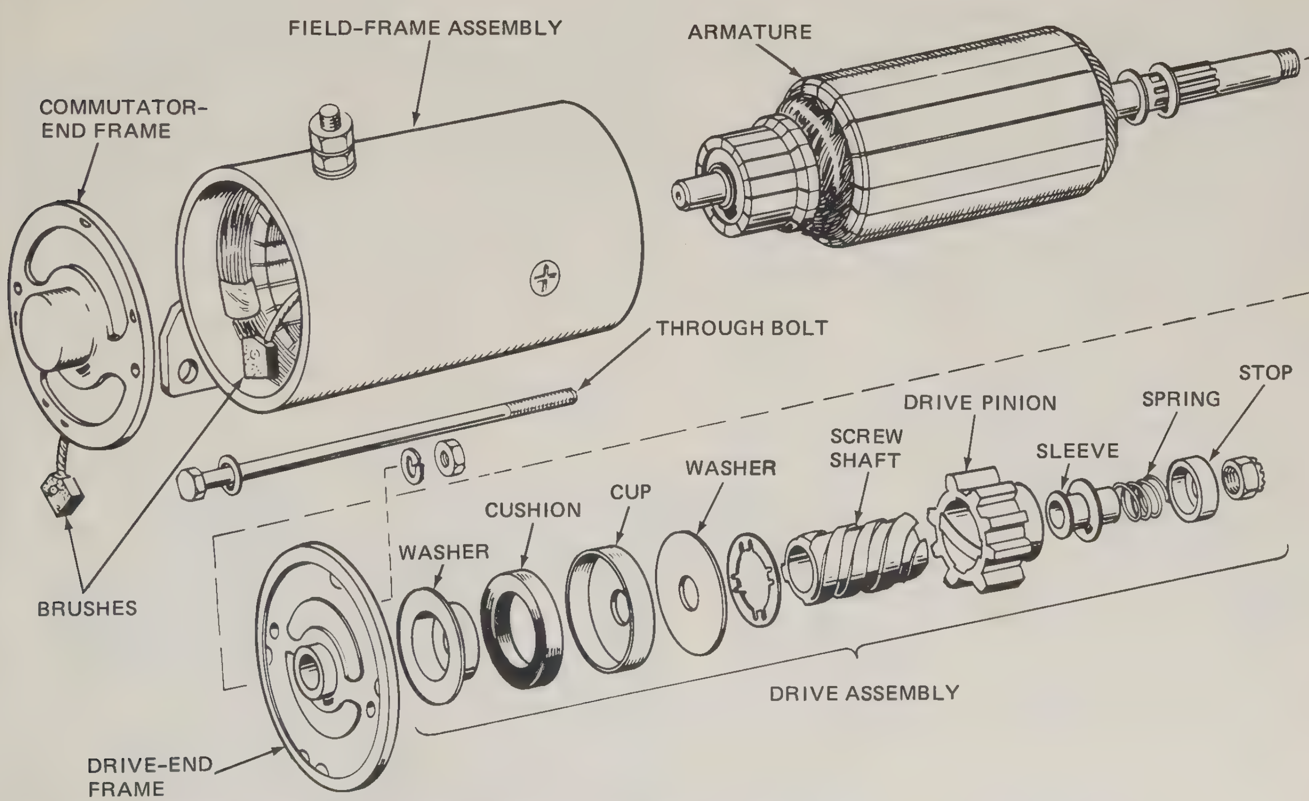


FIG. 23-20 Disassembled view of a rubber-compression-type drive and the starting motor with which it is used. *(Onan Corporation)*

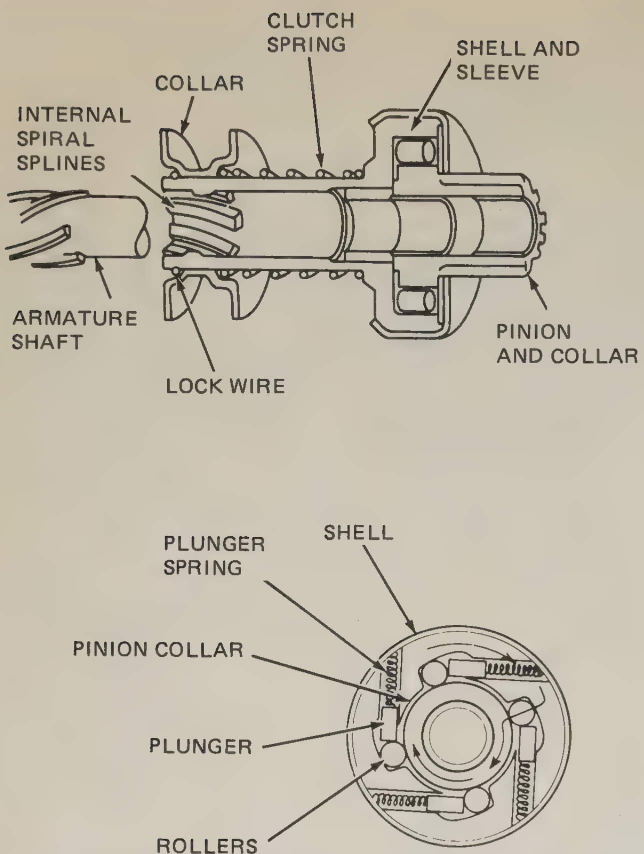


FIG. 23-21 Cutaway and end sectional views of an overrunning clutch. *(Delco-Remy Division of General Motors Corporation)*

ated either by manual linkage or by a solenoid (Fig. 23-18). When the shift lever is operated, it moves the clutch assembly endways along the armature shaft and the pinion drops into mesh with the flywheel teeth. If the teeth should butt instead of mesh, the clutch spring compresses and spring-loads the pinion against the flywheel teeth. Then, as soon as the armature begins to rotate, the pinion will mesh.

Full shift-lever travel closes the starting-motor switch contacts and the armature begins to revolve. This rotates the shell-and-sleeve assembly in a clockwise direction (in the end view of Fig. 23-21). The rollers rotate between the shell and the pinion collar, moving away from their plungers and toward the sections of the notches in the shell, which are smaller. This jams the rollers tightly between the pinion collar and the shell, and the pinion is forced to rotate with the armature and crank the engine. Figure 23-22 illustrates the engaging action in a solenoid-operated starting motor.

When the engine begins to operate, it attempts to drive the starting-motor armature, through the pinion, faster than the armature rotates under its own power. Therefore, the pinion rotates faster than the shell, turning the rollers back toward their plungers, where there is enough room to let them slip freely. The pinion-and-collar assembly can now overrun the shell-and-sleeve assembly and the armature. This gives the armature enough protection for the short time that the operator leaves the ignition switch in the START position after the engine has started (or until the automatic controls take over and open the starting-motor control circuit). When the pressure on the shift lever is relieved, the shift-lever spring slides the clutch assembly back along the armature shaft so that the pinion is demeshed. At the same time, the starting motor switch is opened.

○ 23-12 STARTING-MOTOR CONTROLS

Starting-motor controls (shown in Fig. 23-10) have varied from a simple hand- or foot-operated switch to automatic devices that close the circuit when the accelerator is depressed. The system used today for many small engines has starting contacts in the ignition switch. A typical key-and-ignition switch for starting-motor control on a small engine is shown in Fig. 23-23. When the ignition key is turned against spring pressure past the ON position to START, the starting contacts close. This connects the starting-

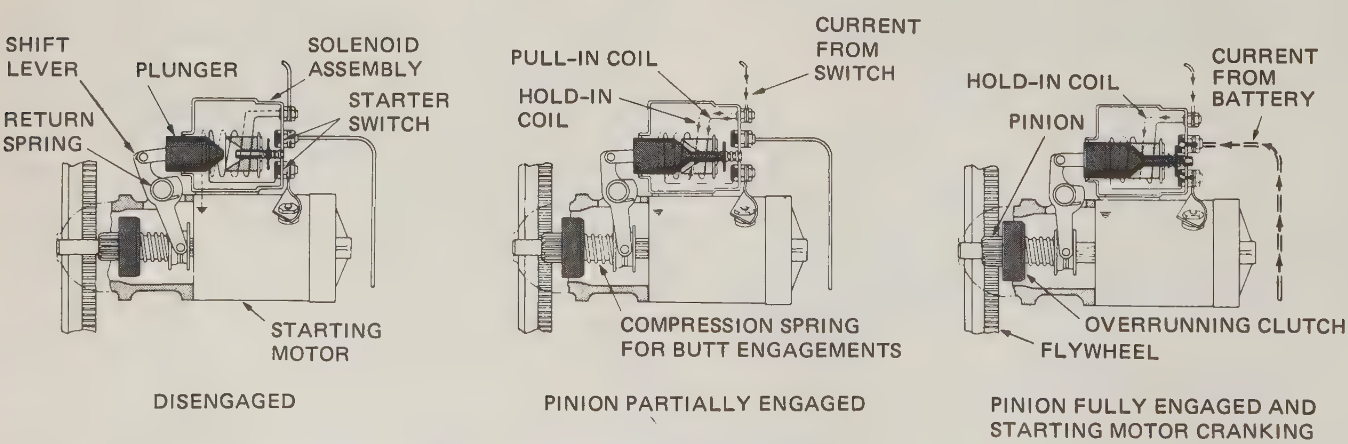


FIG. 23-22 Actions of the solenoid and overrunning clutch as the pinion engages. *(Chevrolet Motor Division of General Motors Corporation)*

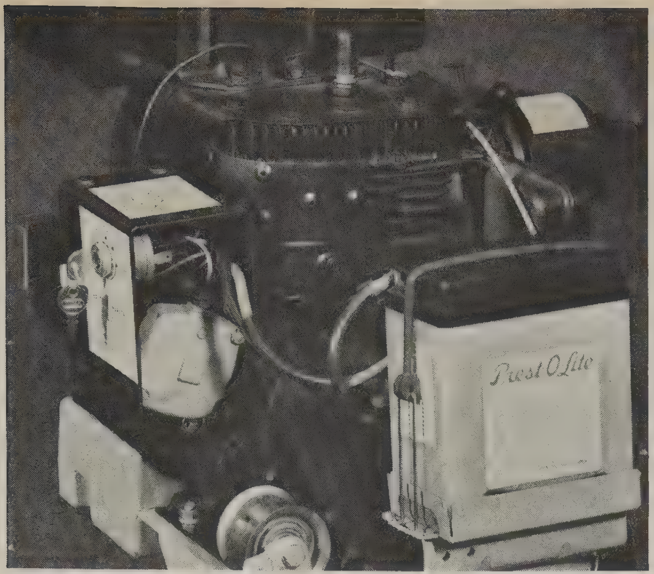


FIG. 23-23 A key-and-ignition switch used for starting-motor control on a small engine. *(Ariens Company)*

motor or magnetic switch to the battery. The solenoid or magnetic switch then operates to connect the battery directly to the starting motor. As soon as the engine starts, the operator releases the pressure on the ignition switch. A spring then returns it from the START to the ON position. This disconnects the starting motor from the battery and so the starting motor stops. However, the ignition remains connected to the battery so that it and the engine continue to function.

○ 23-13 MAGNETIC SWITCH

The magnetic switch depends on the fact that a flow of current in a winding creates a magnetic field. The winding is wrapped around a hollow core, and a cylindrical iron plunger is placed partway into this core. When the winding is energized, the resulting magnetic field pulls the plunger farther into the core (Figs. 23-24 and 23-25). A contact disk is attached to the plunger, and two contacts are placed so that the plunger movement forces the disk against the contacts. This closes the circuit between the battery and the starting motor.

Some magnetic switches have two windings

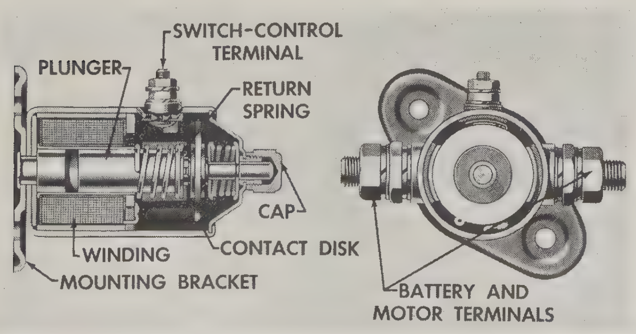


FIG. 23-24 Typical magnetic switch. *(Delco-Remy Division of General Motors Corporation)*

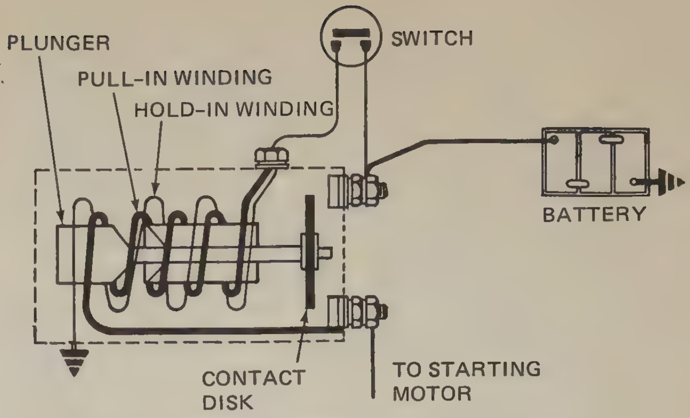


FIG. 23-25 Schematic wiring circuit of a magnetic switch with two windings: a pull-in winding and a hold-in winding.

(Fig. 23-25). There is a pull-in winding of a few turns of heavy wire and a hold-in winding of many turns of fine wire. When the control switch is closed, current from the battery flows through both these windings. The current returns to the battery from the hold-in winding directly through ground. The current passing through the pull-in winding must flow through the starting motor before returning through ground to the battery. This hookup may seem unnecessary. But its purpose is to short out (across the main switch contacts) the pull-in winding when the magnetic switch operates, pulls in the plunger, and forces the contact disk against the two contacts. Shorting out the pull-in winding lessens the drain on the battery and leaves more energy for cranking. More magnetism is needed to pull the plunger in, so both windings work together to accomplish this. But once the plunger is in, less magnetism is needed to hold it in. Therefore, the pull-in winding is shorted out. Only the hold-in winding operates to hold the plunger in place as long as the control switch remains closed.

○ 23-14 SOLENOID SWITCH

On most automobile vehicles and some small engines, overrunning-clutch starting motors use a solenoid to move the overrunning clutch and close the starting-motor switch. The solenoid is larger than the magnetic switch and is mounted on the starting motor, as shown in Fig. 23-18. When the solenoid operates, it first shifts the drive pinion into mesh with the flywheel teeth (Fig. 23-22). Then it closes the circuit between the battery and the starting motor.

The solenoid has two windings: a pull-in winding and a hold-in winding. The pull-in winding is connected across the starter-switch contacts in the solenoid. Both windings work together to pull the solenoid plunger in and move the overrunning clutch pinion into mesh. But once mesh is completed, it takes much less magnetism to hold the plunger in. Therefore, the pull-in winding is shorted out as the main contacts are connected by the solenoid disk.

○ 23-15 SAFETY INTERLOCKS For the operator's safety, manufacturers of equipment such as garden tractors, riding mowers, and snowblowers install a *safety interlock* in the cranking circuit or in the ignition system. These safety interlocks allow the engine to be cranked only when the transmission is in neutral, when the power takeoff is disengaged, or when the operator is sitting on the seat of the vehicle.

Figure 23-26 shows in schematic view an engine that has electric starting and battery ignition (discussed in Chap. 25). Notice that in the safety-interlock circuit on the vehicle, there are three electric switches wired in series. Each switch is spring-loaded to hold it in the open position. When some action takes place—for example, when the operator sits down on the seat—the switch closes. When the proper actions have been taken to close all three switches, then turning the key in the ignition switch will activate the starter.

CAUTION: If the engine must be cranked with the safety interlock bypassed, make sure that all safety conditions are such as to permit the engine to operate safely. This is to prevent personal injury to you or someone nearby or damage to the engine or equipment. You must *never* leave the safety interlock bypassed or disconnected when the equipment is returned to the owner. There is a possibility that you could be held liable for any subsequent injuries or property damage.

120-VOLT STARTERS

○ 23-16 ELECTRIC STARTERS Some engines use starters that are powered from the 120-volt home or shop wiring outlet. The starter is connected by an extension cord to the electric outlet as shown in Fig. 23-27.

CAUTION: When using the 120-volt starter, connections should always be made at the 120-volt outlet receptacle, as shown in Fig. 23-27, and never at the starter. If you make or break the electrical connection at the starter, the spark could ignite gasoline vapor from the carburetor and you could have a fire. Always make sure the extension cord is in good condition, without frayed insulation. The extension cord should be of the type having the third or ground lead.

○ 23-17 120-VOLT ELECTRIC-STARTER DRIVES The 120-volt electric starter uses a small electric motor which develops sufficient power to spin the engine crankshaft and get the engine started. There are several types of electric starters. One is very similar to the type used on a battery-powered starter, covered earlier in this chapter. The other two types use different drive arrangements that are special for small engines.

○ 23-18 CONE-DRIVE 120-VOLT STARTER One type of 120-volt electric starter, shown in Fig. 23-28, uses a cone-shaped friction-drive clutch. To operate this starter, press down on the switch-control button. This connects the electric motor to the 120-volt source so it spins. As soon as it gets up to speed, then press down on the starter housing. This engages the cone-shaped drive clutch so that the flywheel and crankshaft are spun. When the engine starts, release the starter housing and the switch-control button. The release springs lift the starter housing so the clutch disengages. At the same time the spring under the switch-control button lifts the button so that the starter motor is disconnected from the 120-volt source.

○ 23-19 SPLIT-PULLEY-DRIVE 120-VOLT STARTER This type, shown in Fig. 23-29 also engages by friction, but it does this automatically. The upper part of Fig. 23-29 shows how the split-pulley drive operates. When the starter is not operating, the two halves of the pulley are apart, as shown to the upper left. When the starter is operated, the upper half of the pulley comes up to speed along with the motor armature and shaft because the upper half of the pulley is attached to the shaft. The lower half of the pulley, being somewhat free, does not pick up speed instantly. Instead, it lags behind because of inertia. Inertia is that property that all things have which resists change of position. Therefore, the lower pulley half is momentarily stationary. The pin in the motor shaft then pushes against the ramp in the lower pulley half, forcing the pulley half to move upward, as shown to the upper right in Fig. 23-29. Now the sides of the two pulley halves clamp the drive belt so that the drive belt is forced to move. This causes the drive pulley located above the engine flywheel to spin, thereby cranking the engine.

After the engine starts and the motor is disconnected from the 120-volt source, the belt tension applied to the pulley forces the lower half to continue to move for a moment. This allows the lower half to drop down to the disengaged position, as shown to the upper left in Fig. 23-29.

○ 23-20 BENDIX-DRIVE 120-VOLT STARTER This starter is very much like the electric starting motors with Bendix drive that are battery-powered. At one time, the Bendix drive was used on many automotive starting motors, but today most use an overrunning clutch. The Bendix drive is used in some small-engine starters because of its simplicity. We described the Bendix drive in ○ 23-10.

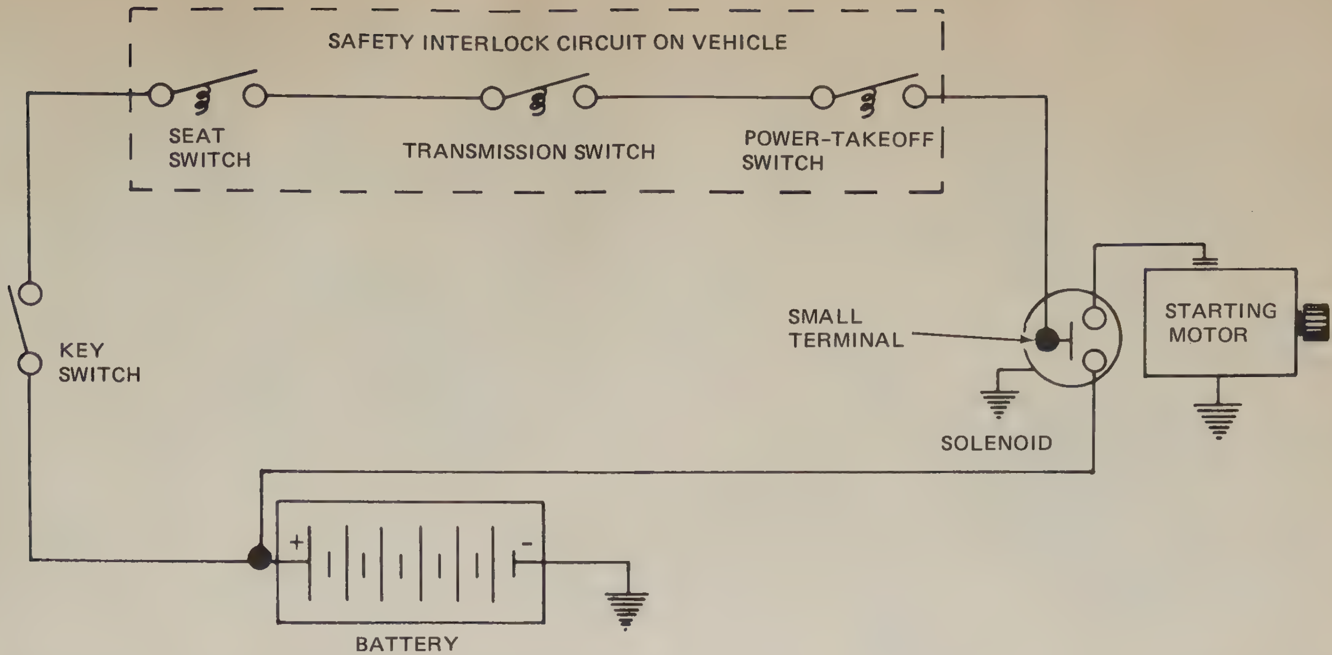


FIG. 23-26 A typical safety interlock system. *(Kohler Company)*

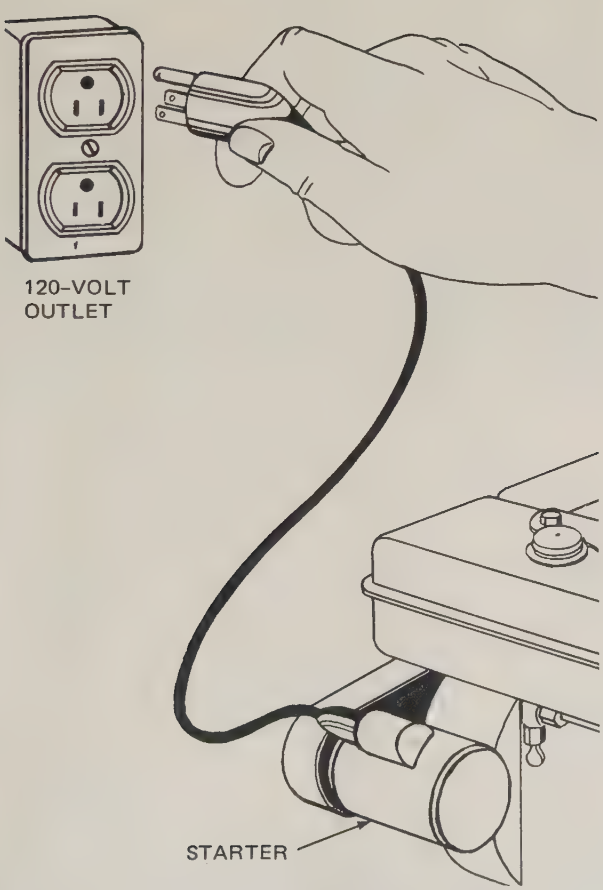


FIG. 23-27 Electric starter which uses house current to operate. *(Briggs & Stratton Corporation)*

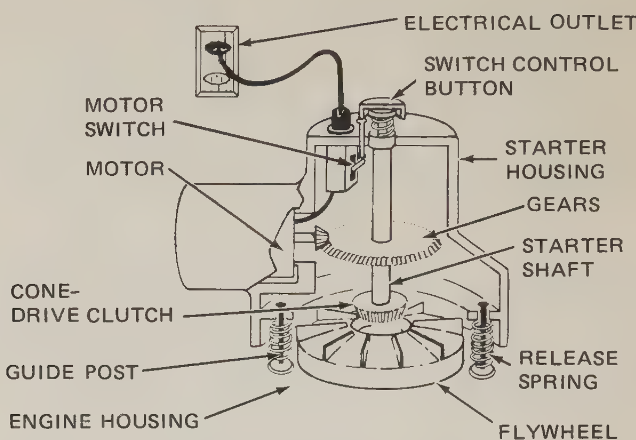


FIG. 22-28 Details of the cone-drive mechanism used with a 120-volt starter. Parts are shown separated so their relationship can be seen.

○ 23-21 STARTER-GENERATOR In many small-engine installations using battery-type electric starting motors, the starter may also be a generator. This makes it a starter-generator assembly. As a starter, it cranks the engine to start it. Then when the engine is running, the starter-generator acts as a generator to produce current that puts back into the battery the current taken out by the starting cycle.

Figure 23-30 shows a typical wiring circuit for a starter-generator system. It includes a generator regulator, which is described later. The starter-generator is connected by a V-belt to the engine, as shown in Fig. 23-31, and is continuously connected during both cranking and generating. The starter-generator has two sets of field windings, one for cranking the engine and the other for producing current. When the starter switch is closed, battery current flows through the starter field windings. These windings are made

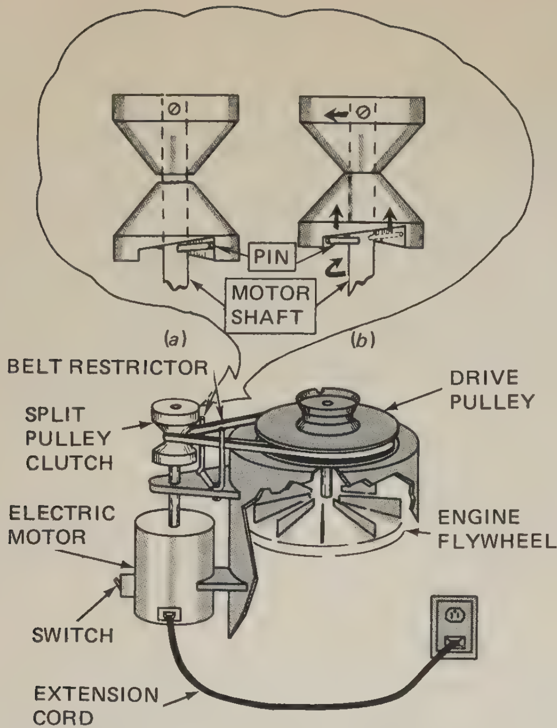


FIG. 23-29 Details of the split-pulley-drive mechanism used with a 120-volt starter. Parts are shown schematically so their relationship can be seen. The top views, *(a)* and *(b)*, show the two positions of the lower pulley half: at left, not cranking; at right, cranking.

of heavy copper wire so that a heavy current can flow from the battery through them. This produces a strong magnetic field, which results in a strong cranking effort. The armature is spun and the engine crankshaft is rotated so that the engine starts.

Then the operator opens the starter circuit by releasing the starter switch. This opens the starter field windings so starter action is ended. Now, as the engine comes up to speed and drives the starter-generator, the generator begins to produce current. A magnetic field is produced in the generator by the

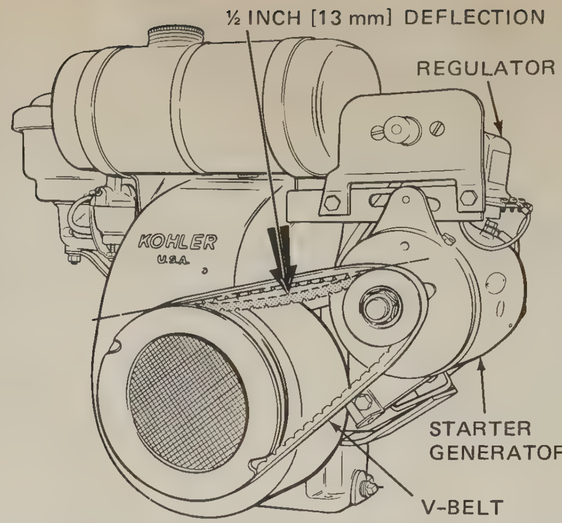


FIG. 23-31 Belt drive for a starter-generator. Proper belt tension is indicated as allowing 1/2-inch [12.7 mm] deflection and is adjusted by moving the starter-generator toward or away from the engine. *(Kohler Company)*

generator field windings, which are made up of relatively light copper wire. These windings are shunted, or connected across, the armature and use up a small part of the current that the armature produces. This creates a magnetic field in which the armature spins. The armature windings, which have been serving as starter windings during the starting cycle, now begin to serve as current producers.

Figure 23-32 shows schematically two variations of the basic starter-generating system, one using a starter solenoid. The purpose of the solenoid is to make it possible for the starter switch to be located some distance away from the battery and starter. This reduces the length of heavy cable needed to make the circuit between the battery and starter. Only a light wire is needed between the switch and solenoid, because the solenoid needs only a small amount of current to make it work. (The bigger the current flow, the heavier the wire needed to carry it.)

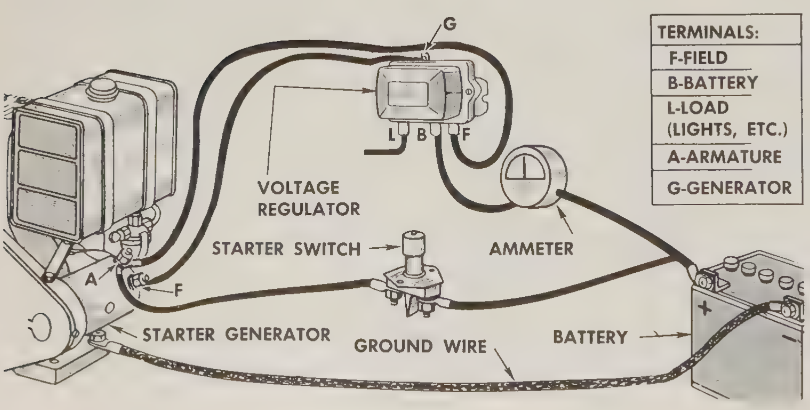


FIG. 23-30 Wiring circuit of a typical starter-generator system. The starter-generator starts the engine, and then generates current to charge the battery. The system includes a regulator to control the generator.

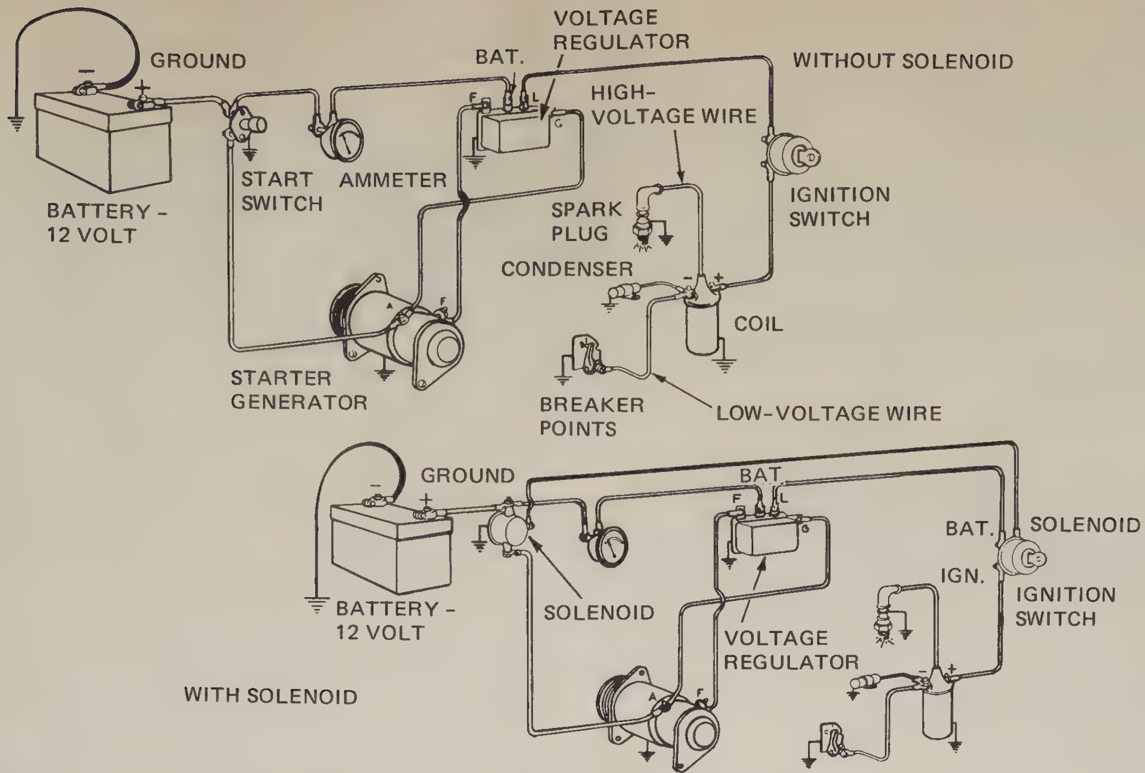


FIG. 23-32 Wiring diagrams of two types of starter-generator systems, one without a solenoid and the other with a solenoid. *(Kohler Company)*

When the switch is turned to SOLENOID for starting, the solenoid is connected to the battery and it produces a magnetic field. This magnetic field pulls in an iron plunger which forces heavy contacts to close. These heavy contacts make a direct connection from the battery to the starter so that the engine is cranked. The system shown in Fig. 23-32 includes an ignition system. This is a battery ignition system which is discussed in Chap. 25. The generator and regulator also are described in later chapters covering charging systems.

REVIEW QUESTIONS

1. What are the two general types of starters used on small engines?
2. What are the advantages of a mechanical starter?
3. What are the advantages of an electric starter?
4. What is the difference between a rope-wind and a rope-rewind starter?
5. Describe the operation of a windup starter.
6. What type of engines usually have a kick starter?
7. What type of electric starter is used on equipment such as riding mowers and lawn and garden tractors?
8. What are the two main parts of the battery-powered starting motor?
9. What makes the starting motor operate?
10. What is a starter drive?
11. Why must the starting-motor pinion be demeshed from the flywheel as soon as the engine starts?
12. Explain how the Bendix drive works.
13. Explain how the overrunning clutch works.
14. What is the most common type of starting-motor control?
15. What job does the magnetic switch do in the starting system?
16. Why does the starting-motor solenoid have two windings?
17. What is the difference between a magnetic switch and a solenoid?
18. What is a safety interlock?
19. Why should you never disconnect or bypass a safety interlock for a customer?
20. Describe the operation of a cone-drive on a 120-volt starter.
21. Explain the operation of the split-pulley drive on a 120-volt starter.
22. What is a starter-generator?

23. How is a starter-generator connected to the engine crankshaft?

24. What is the difference between the two types of starter-generator systems?

SELF PROJECTS

1. Using the set of school shop manuals for small engines, make a list of engines and the type of starter used on each engine. Notice that some engines have more than one starter available.

2. Locate a discarded starter for a small engine. Disassemble the starter and clean the parts. Then mount them on a board for display in the school shop or classroom. Label each of the parts in the starter.

24
Chapter

Servicing Small-Engine Starters

After studying this chapter, you should be able to:

1. **List the steps in troubleshooting mechanical starters**
2. **Demonstrate how to service each type of mechanical starter**
3. **Explain how to troubleshoot electric starters**
4. **List the possible causes of the trouble if the starting motor does not operate or if it operates slowly but the engine does not start**
5. **Demonstrate how to rebuild and test a starting motor**
6. **Describe how to test the starting-motor drive**

○ 24-1 TROUBLESHOOTING MECHANICAL STARTERS The following points should be kept in mind whenever you begin to solve a starting problem:

1. Look for obvious troubles first, such as a broken rewind spring, a weak battery, poor battery connections, or a defective starter drive.
2. Try to pinpoint the trouble before removing the starter.
3. On electric starters, disconnect the battery cable before removing the starter.
4. Disassemble the starter only as far as necessary to correct the trouble.
5. Test the starter before reinstalling it.
6. Wear safety goggles and follow all safety precautions when working on mechanical starters.

When troubleshooting mechanical starters, first determine if the starter is really the problem. Generally, if the mechanical starter is able to crank the engine, the problem is elsewhere—possibly in the ignition or fuel system. However, in the study of ignition systems you will find that most small engines require normal cranking speed to generate ignition voltage. So you must be sure that the starter is cranking the engine at the proper speed. After operating a few mechanical starters, you will be able to "feel" how much power they have. You will be able to sense what "normal" cranking speed should be.

Figure 24-1 shows typical procedures to follow when troubleshooting mechanical starters. The chart does not list all the problems that could happen, nor the obvious ones, such as a broken pull-rope or handle.

CAUTION: Some types of mechanical starters have powerful springs wound up inside. Use caution when

MECHANICAL STARTER TROUBLESHOOTING CHART

Condition	Check or Correction
1. Starter spins but engine does not crank	a. Check engagement of starter pawls, rachet, or dogs
2. Engine cranks but starter pull has no feel of tension (rope-wind and rope-rewind starter)	a. Check engine compression
3. Rope does not rewind on starter (rope-rewind starter)	a. Check operation of rewind spring
4. Starter slips while cranking engine	a. Check starter pawls, dogs, or rachet teeth
	b. Check flywheel teeth
	c. Check for dirt or grease in drive mechanism
5. Starter does not wind up (wind-up starter)	a. Check windup spring
6. Starter does not crank engine fast enough	a. Check that starter engages and does not slip
	b. Check starter spring (windup starter or kick starter)
	c. Check for engine drag
7. Engine cranks properly but does not start	a. Check ignition system for spark
	b. Check fuel system for fuel, water in fuel, line obstructions, and overchoking
	c. Check engine for low compression

FIG. 24-1 Troubleshooting chart for mechanical starters.

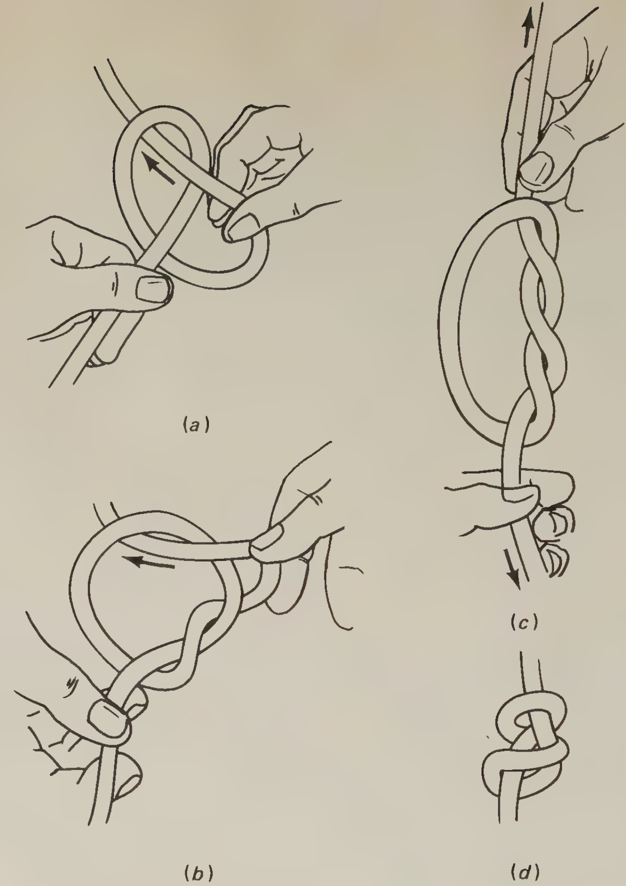


FIG. 24-2 How to make a double-overhand knot.

taking these starters apart. If the starter is improperly disassembled, the spring could unwind with considerable force. To prevent eye injury, wear safety goggles when working with the starter spring.

○ 24-2 ROPE-WIND STARTERS

This type of starter operates by winding several turns of rope around the engine flywheel pulley, then pulling it quickly to crank the engine. The only parts usually needing service on this type starter are the rope and handle. You can buy a new rope and handle assembly, or either part if only one goes bad. The new rope should be the same size and length as the old one. Most engines use a 3/16-inch [5-mm] nylon braided rope about 5 feet [1.5 m] long. The rope should be long enough to wrap around the flywheel pulley up to five times plus an additional 1 foot [305 mm] to make knots at the two ends.

Two kinds of knots can be used to hold the rope in the handle at one end and on the pulley at the other. The procedure for making the knots is illustrated in Figs. 24-2 and 24-3. Some handles use a pin tied into

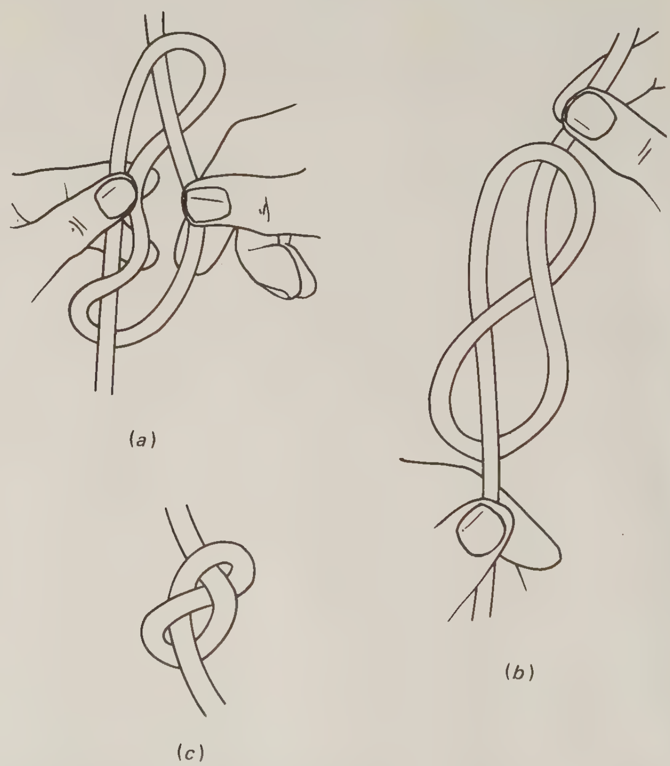


FIG. 24-3 How to make a figure-eight knot.

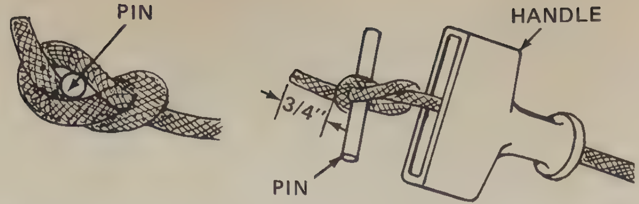


FIG. 24-4 Handle retained by a pin tied into the knot. (*Briggs & Stratton Corporation*)

the knot to retain it in the handle as you see in Fig. 24-4. Before making any knots in the rope, singe both ends with a match to prevent the rope from unraveling. This procedure also assures that the knots will not slip and loosen after they are tied. In servicing any rope-pull starter, replace the rope if it is frayed or ragged.

○ 24-3 ROPE-REWIND STARTERS The rope-rewind starter uses a pull-rope with a powerful spring to rewind the rope after it is pulled out for cranking. Several designs of this type of starter are in use. All work on the same general principle but require different servicing procedures. General servicing procedures for rope-rewind starters include replacing the rope, replacing the spring, and repairing the drive mechanism.

○ 24-4 REPLACING THE ROPE Remove the starter from the engine. Usually the starter is attached by three or four screws. On some engines, you must remove a top cover or other piece to get to the starter. You can work on the starter if it is laid on a workbench, but you will find it easier to work on if you

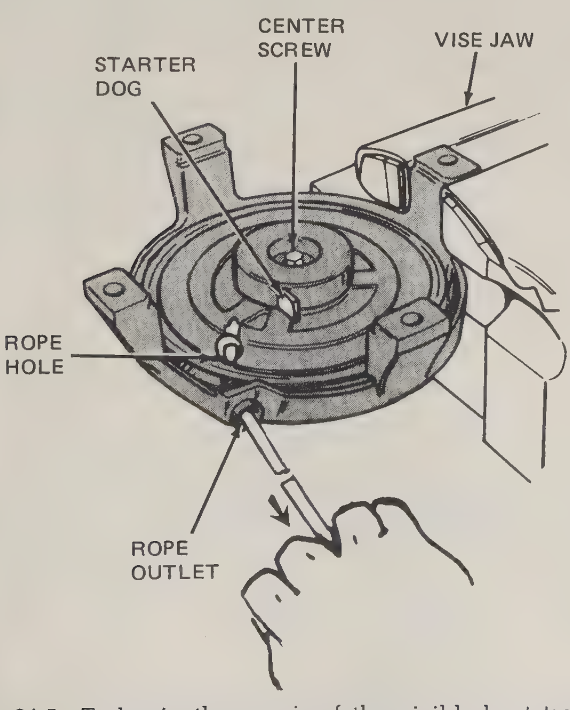


FIG. 24-5 To begin the repair of the visible-knot type of rope-rewind starter, pull the rope all the way out.

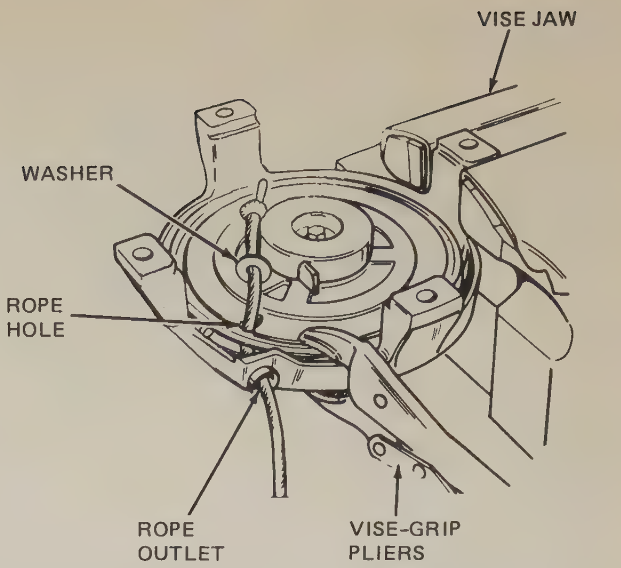


FIG. 24-6 Holding the pulley with Vise-Grip pliers. (*Tecumseh Products Company*)

clamp it upside down in a vise, as shown in Fig. 24-5. If the knot in the rope is visible, you will be able to replace the rope without disassembling the starter. If the knot is not visible, you will have to disassemble the starter. With the starter disassembled, always check the spring. When the rope breaks, it sometimes bends the spring.

On the visible-knot starter, shown in Fig. 24-5, pull the rope all the way out against the tension of the recoil spring. The pulley must be held in place so the spring does not unwind when the new rope is installed. You can hold the pulley with Vise-grip pliers as shown in Fig. 24-6, or you can use a wrench and square stick as shown in Fig. 24-7. When the wood-

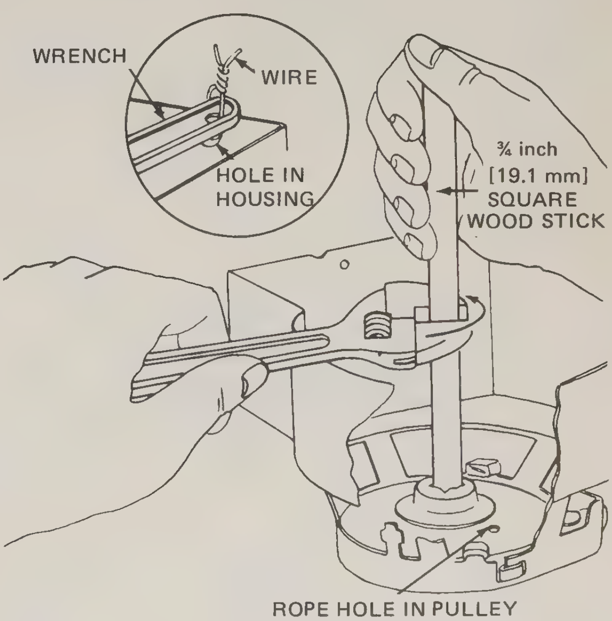


FIG. 24-7 On some starters you can hold the pulley, or wind up the recoil spring, with a square piece of wood and a wrench. (*Briggs & Stratton Corporation*)

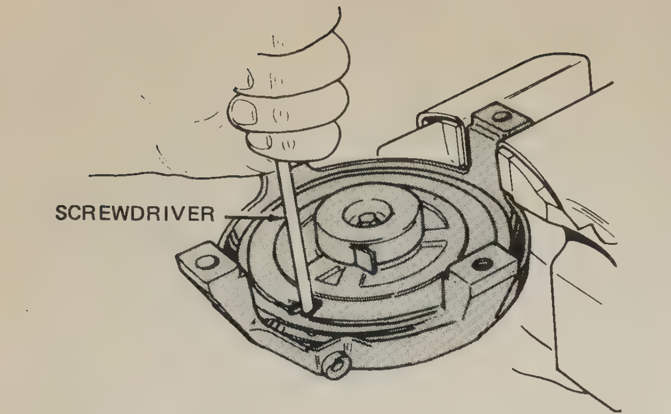


FIG. 24-8 On some starters, you can wind up the recoil spring with a screwdriver.

stick rewind method is used, the end of the wrench is wired to the housing, as shown in the inset in Fig. 24-7.

If the spring has no tension when the rope is pulled out, the spring has unwound. You can wind it up again with a wrench and square stick or with a screwdriver as shown in Figs. 24-7 and 24-8.

Whenever you wind up a starter spring, always make sure you wind it in the correct direction. The general rule is to wind the spring up tight and then back it off one complete turn. If the spring cannot be wound up, it is probably broken or detached. We will discuss how to service the spring later.

The new rope should be the same size and length as the old. Singe both ends of the rope with the flame of a match. This prevents the rope from fraying and also prevents the knot from loosening. Thread the rope through the rope eyelet in the housing and then through the hole in the pulley, as shown in Figs. 24-9 and 24-10. If the holes line up, threading the rope is not difficult. But when the holes do not line up, threading is made easier by using a hooked wire

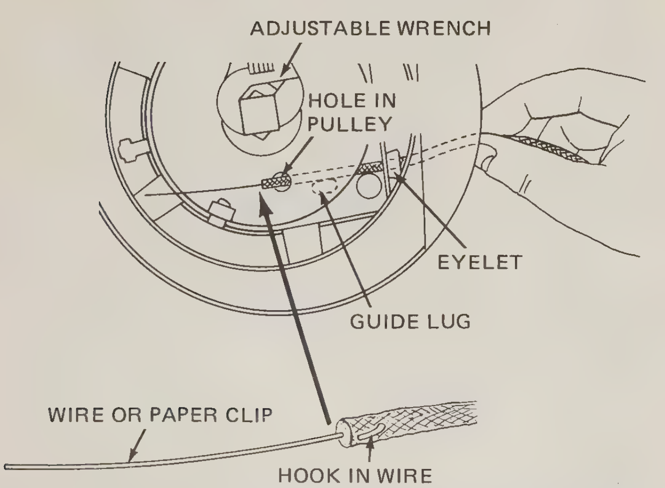


FIG. 24-9 When rethreading the rope into the pulley hole, you may find that a piece of wire hooked into the end of the rope, as shown at the bottom, will make it easier.

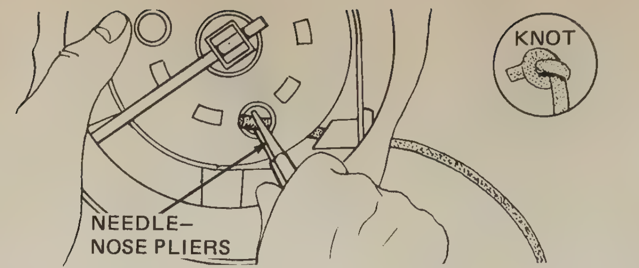


FIG. 24-10 Installing the rope on a starter that does not have a guide lug. (*Briggs & Stratton Corporation*)

through the rope end, as shown in Fig. 24-9. On this starter, be sure that the rope passes on the inside of the guide lug. After the rope is in the pulley, tie a knot in the rope end. On some starters, a thin washer with a $^3/_4$-inch [19-mm] diameter and a $^1/_4$-inch [6.35-mm] hole is inserted on the rope before the knot is tied as shown in Fig. 24-6. When the knot is tied, pull the rope so the knot is near the hole and does not interfere with anything when the pulley rotates. Now, with the rope pulled taut, release the Vise-grip pliers or the wrench holding the wood stick. Slowly let the rope wind up on the pulley. Then attach the handle to the other rope end, as explained earlier for rope-wind starters.

On the hidden-knot starter, the knot is not visible and the starter must be disassembled to replace the rope. Disconnect the handle from the end of the rope and untie the knot. Hold the pulley with a cloth or a gloved hand and allow it to turn slowly. This removes the tension on the spring. Then remove the starter drive from the pulley assembly. This requires disassembly of the starter-drive mechanism, which we will cover later. There are two types of pulleys: the one-piece and the two-piece.

The one-piece pulley is shown disassembled in Fig. 24-11. When the starter has a one-piece pulley,

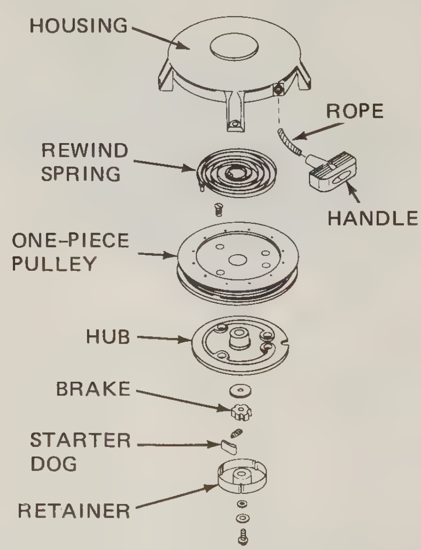


FIG. 24-11 Disassembled rope-rewind starter with one-piece pulley. (*Tecumseh Products Company*)

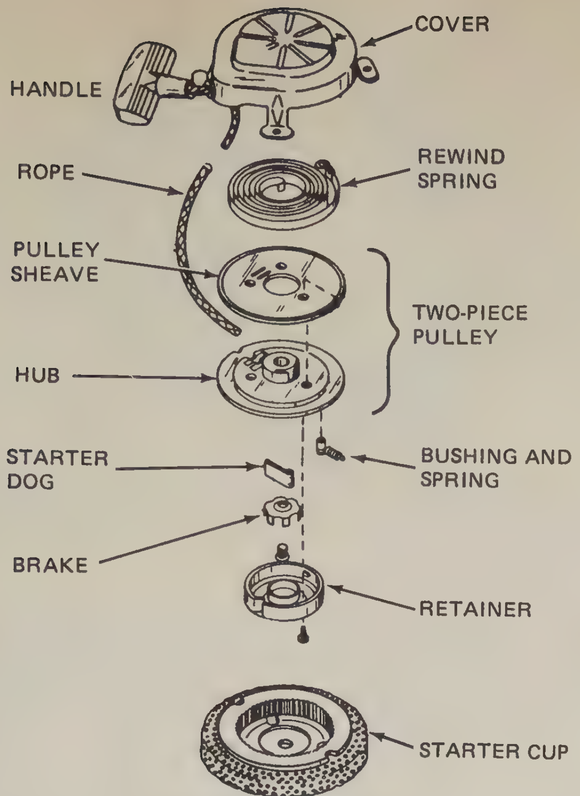


FIG. 24-12 Disassembled rope-rewind starter with two-piece pulley.

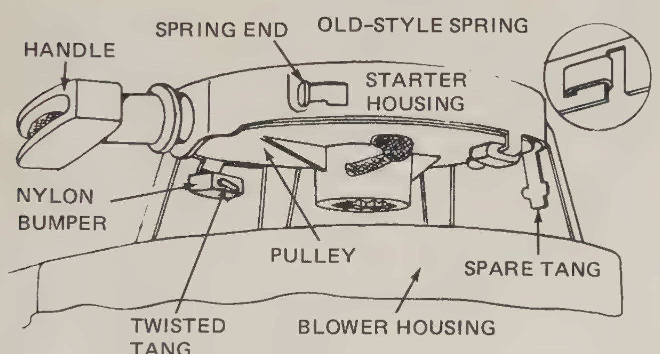


FIG. 24-13 A removable type of recoil spring. The end of this spring can be seen from outside the starter.

remove the pulley, leaving the spring in the housing. Then the rope can be replaced on the pulley, as we have discussed earlier.

Figure 24-12 shows a rope-rewind starter that uses a two-piece pulley. When the starter has a two-piece pulley, remove one side of the pulley, leaving the spring under the other half in the housing. You will now be able to remove the rope and install a new rope, as already explained.

Now reinstall the pulley after winding the rope on it. The drive mechanism is assembled as explained later. Rewind the spring and secure the pulley in place with Vise-Grip pliers or with a wrench and wood stick. Assemble the handle on the rope end so that the pulley cannot unwind. Then release the Vise-Grip pliers or wood stick. Reinstall the starter on the engine, making sure that it is properly aligned. Some starters have an alignment pin which is inserted into a hole in the crankshaft to secure alignment. If the alignment is not correct, the starter will not work properly and will wear out rapidly.

○ 24-5 REPLACING THE SPRING There are two types of recoil springs: the removable type and the packaged type. One removable type is shown installed in a starter in Fig. 24-13. You can recognize it because you can see the spring end on the outside. The packaged type is a stronger spring and comes pre-oiled and compressed inside a retainer housing. The retainer housing may be of the permanent type and is installed in the starter along with the spring. On others, the housing is discarded when the spring is installed in the starter.

If the spring is of the removable type accessible from outside the starter housing, remove the starter and clamp it in a vise. Remove the rope from the handle, and with a gloved hand or cloth, slowly let the pulley rotate to release the spring tension. Pull the spring out of the housing as far as possible with pliers, as shown in Fig. 24-14. Use a cloth or wear

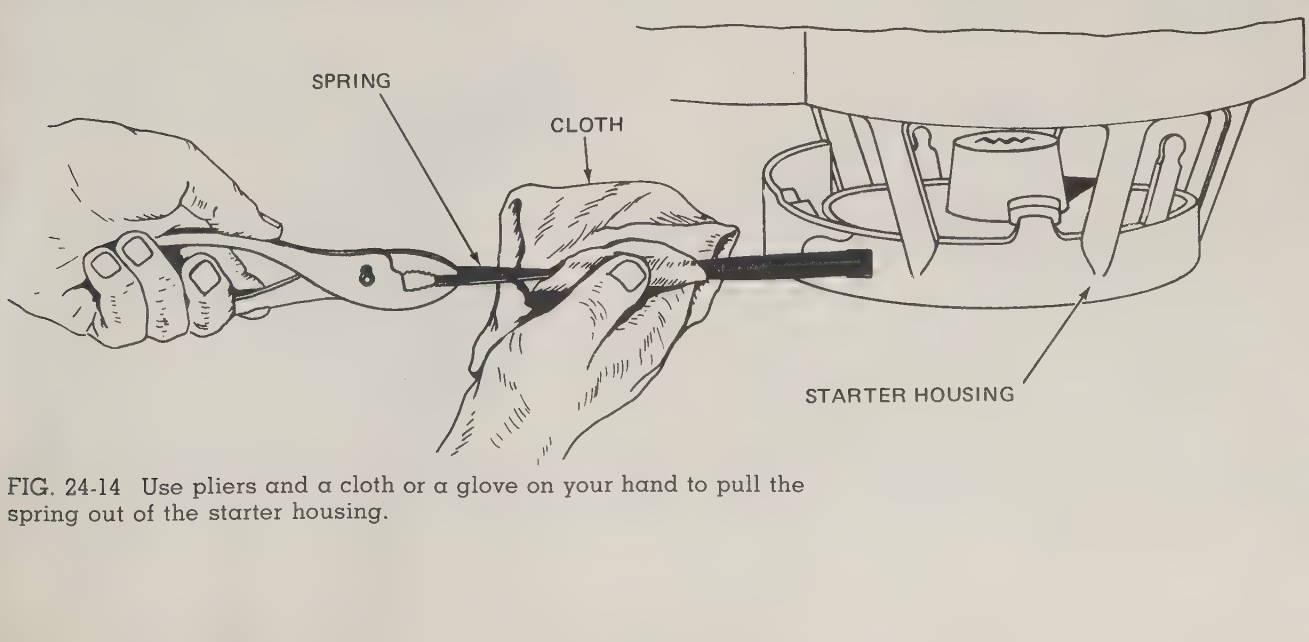


FIG. 24-14 Use pliers and a cloth or a glove on your hand to pull the spring out of the starter housing.

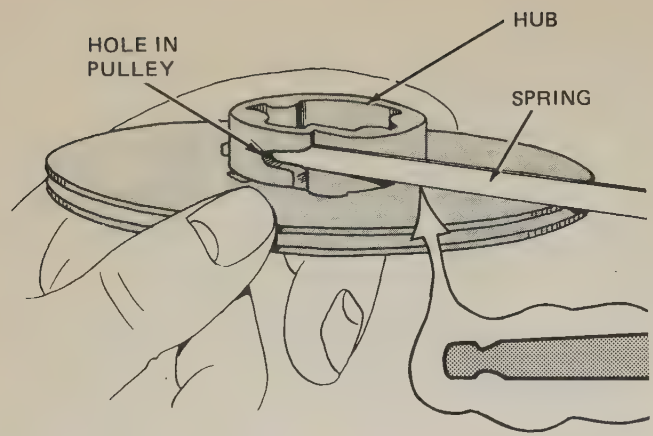


FIG. 24-15 Unhooking the spring from the pulley.

gloves to protect your hands. Remove the pulley. If the pulley is held in place by bumper tangs as shown in Fig. 24-14, bend up one tang to remove the pulley. If the pulley is held in place by the starter-drive mechanism, remove it first. We describe starter-drive service later in this chapter.

Disconnect the spring from the pulley, as shown in Fig. 24-15. If you are going to use the spring again, straighten it, as shown in Fig. 24-16. Wear gloves to protect your hands.

Attach the replacement spring to the pulley. Install the pulley inside the starter housing with the spring extending out, as shown in Fig. 24-14. Now with gloves or cloth protection for your hands, guide the spring into the housing. Let the spring wind up, using either of the methods shown in Figs. 24-7 and 24-8. Be sure the spring end securely locks into the side of the housing at the end of the rewind. Attach the rope to the pulley and install the handle. Then install the starter on the engine and check its operation.

If the spring is of the packaged type, as shown in Fig. 24-17, the retainer housing may be of the temporary type or it may be permanent. If it is temporary, the spring is slid from the temporary housing into the permanent housing on the starter. If the retainer housing is of the permanent type, the old housing is removed from the starter and the new housing with spring is installed.

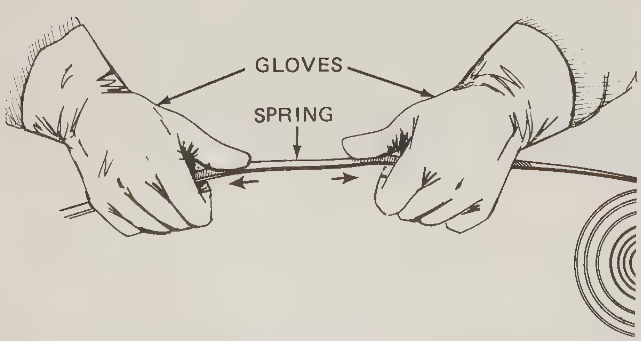


FIG. 24-16 Straightening the spring to provide more tension. Wear gloves when handling the spring.

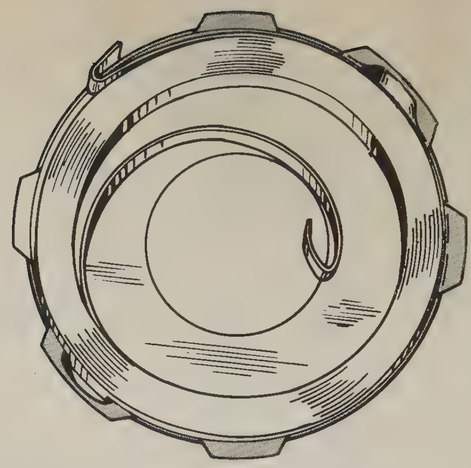


FIG. 24-17 A packaged type of recoil spring. Most replacement recoil springs are enclosed like this in a housing for safe handling.

If the spring is of the semicoiled removable type, it should be removed from its package as shown in Fig. 24-18. The spring can then be wound into the housing on the starter.

○ 24-6 DRIVE-MECHANISM SERVICE

All rope-rewind starters are similar in construction. The main difference is in the ratchet mechanism that causes the pulley to engage the crankshaft for cranking and then releases when the engine starts. There are four general types, as shown in Fig. 24-19, based on the method used for flywheel engagement. These methods are pawls, dogs, friction shoes, and steel balls.

To service the drive mechanism, remove the starter and clamp it in a vise, as shown in Fig. 24-5. Pull the rope and feel the action of the drive mechanism. When the rope is pulled, a properly working drive mechanism should quickly engage the flywheel adapter. If service is required, remove the drive mechanism, as shown in Fig. 24-20. Disassemble it. Note very carefully what parts go where when you take the mechanism apart. Then you will know ex-

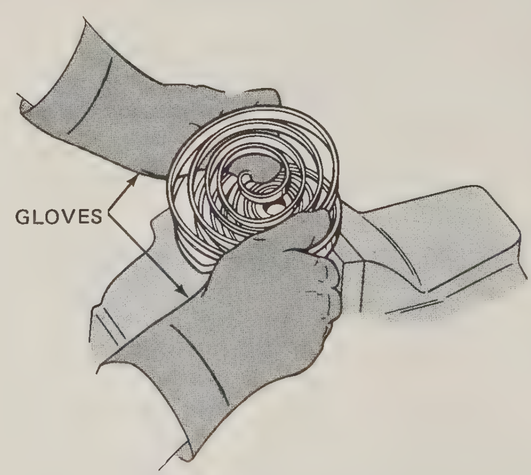


FIG. 24-18 A removable or semicoiled type of recoil spring.

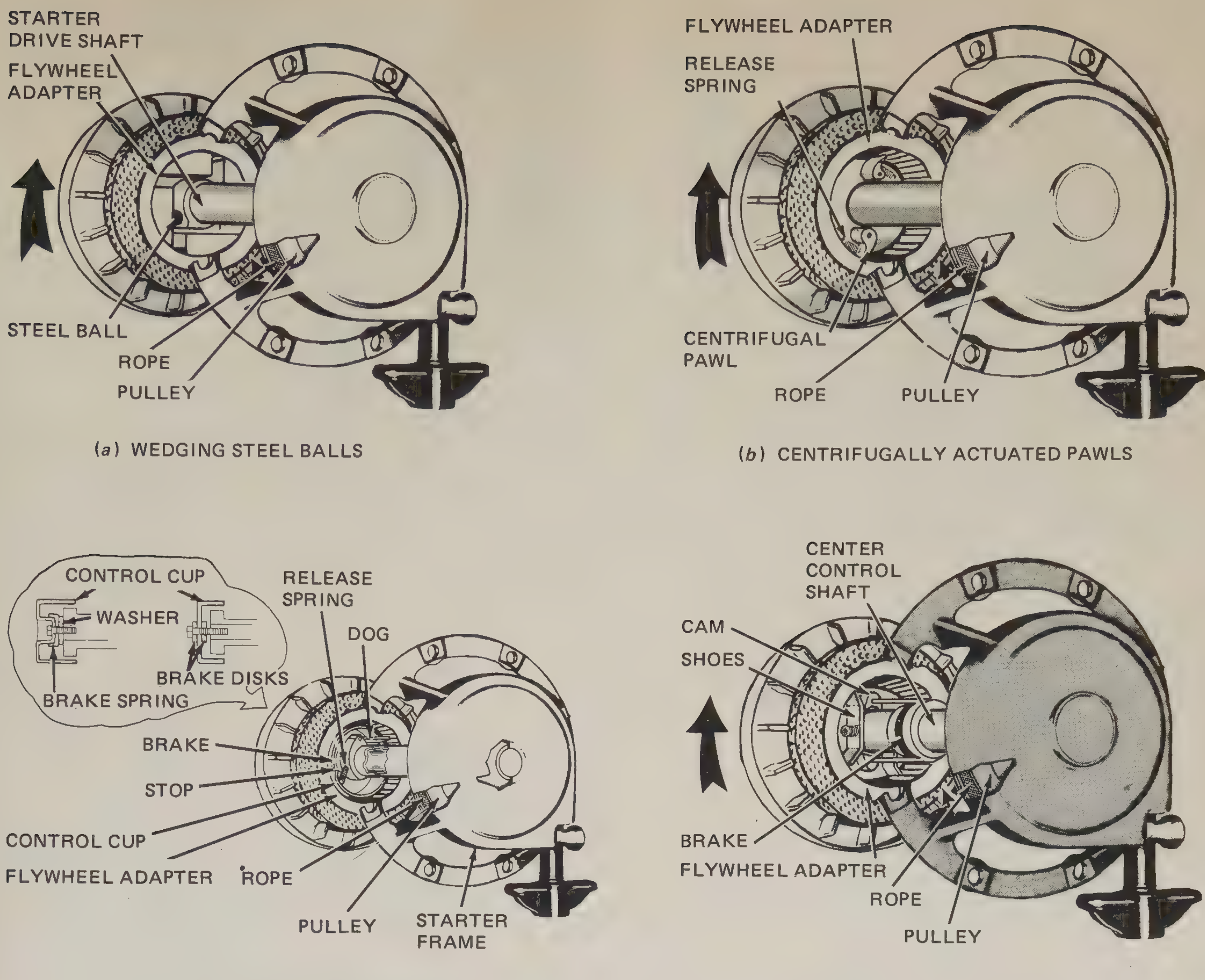


FIG. 24-19 Various types of drive mechanisms for rope-rewind starters.

actly how everything goes together when you reassemble it. Be especially careful to put the engaging mechanism back in exactly the same way you found it. If you get it in wrong, the starter will not work. Lubricate the parts lightly with graphite or multipurpose grease on reassembly.

Check for proper operation after reassembly. Then install the starter on the engine. Recheck the starter for proper operation.

○ 24-7 VERTICAL-PULL STARTERS The rewind starter shown in Fig. 24-21 is used on some outboard engines and lawn-mower engines. It is a vertical-pull starter using a Bendix drive. To service the starter, remove the handle and let the rope slowly recoil to remove the spring tension. Then unscrew the starter-mounting bolt, and remove the starter from the engine. Hold the starter together while removing it to prevent releasing the spring.

To replace the rope on this starter, take off the retainer clip on the end of the Bendix drive and slide off the plastic starter pinion. It is shown in Fig. 24-21. The pinion gear mounts on the worm gear with the grooved side toward the pulley. Remove the screws that hold the pulley plate to the pulley and disassemble the pulley (Fig. 24-22). Obtain the new replacement rope and singe the ends. Remove the old rope and install one end of the new rope in the pulley, as shown in Fig. 24-22. Install the pulley plate on the pulley and tighten the screws. Hold the starter so the worm gear points toward you, and wind the rope clockwise on the pulley.

To install a new starter spring, remove the outer pulley cup and old spring. Curl the end of the new spring on the outside of the starter pulley, as shown in Fig. 24-23. Position the cover over the pulley so that the spring is guided through the slot in the cover. Clamp the starter in a vise using wooden blocks to prevent damage to the worm-gear shaft. Wind the rope on the pulley. Then pull the rope to turn the pulley, as shown in Fig. 24-24. Repeat this as necessary to draw the spring into the cover. The end of the

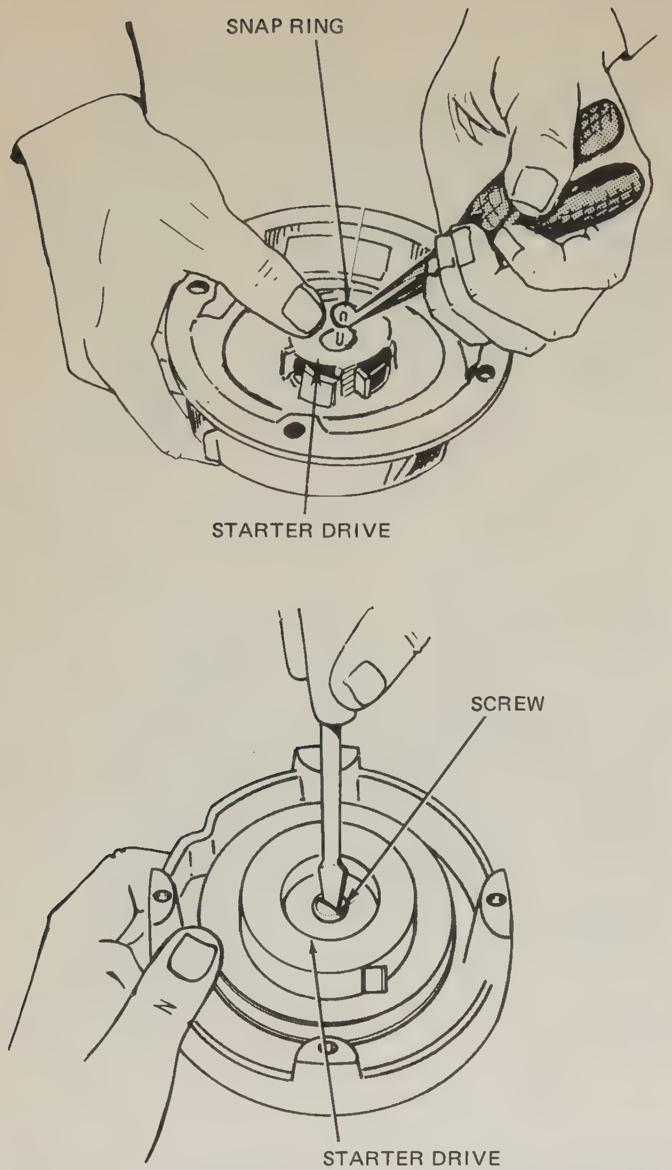


FIG. 24-20 On some models, remove the drive mechanism by removing a snap ring as at (*a*). On others, remove a screw as at (*b*).

starter spring should hook on the cover slot, as shown in Fig. 24-25. Install the starter rope-retainer on the outside of the pulley.

If the starter could be pulled but it did not crank the engine, the pinion spring may be sprung or damaged. A distorted spring will not grip the pinion properly and so the pinion will fail to engage the flywheel. The two prongs of the pinion spring should be 1/4 inch [6.35 mm] or less apart when the spring is off the pinion. If the spring needs replacement, use care to stretch the new one only wide enough to allow it to snap into the groove of the pinion.

Place the starter assembly on the engine with the end of the starter spring up and in the cutout made for it, as shown in Fig. 24-26. One prong of the starter-pinion spring should be above the mounting plate edge and the other prong below it. The starter-rope

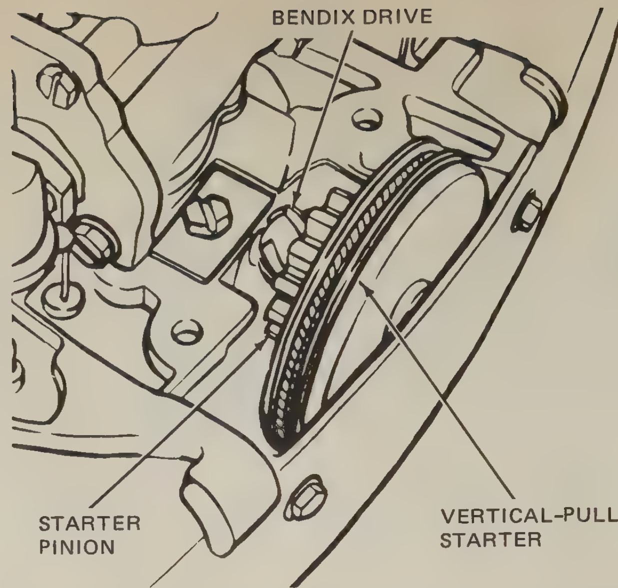


FIG. 24-21 Vertical-pull rope-rewind starter using a Bendix drive. (*Evinrude Motors Division of Outboard Marine Corporation*)

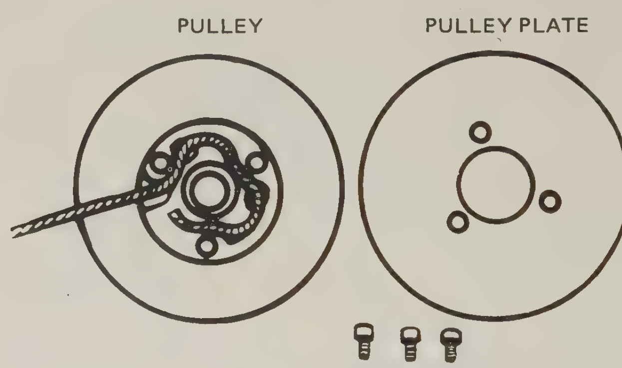


FIG. 24-22 Position of the rope in the pulley. (*Evinrude Motors Division of Outboard Marine Corporation*)

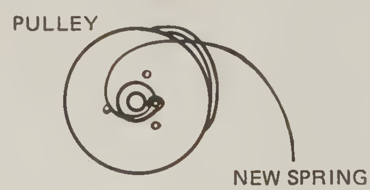


FIG. 24-23 Installing a new starter spring. (*Evinrude Motors Division of Outboard Marine Corporation*)

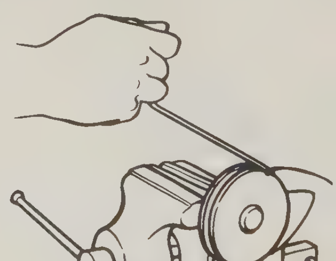


FIG. 24-24 Winding the new spring into the cover. (*Evinrude Motors Division of Outboard Marine Corporation*)

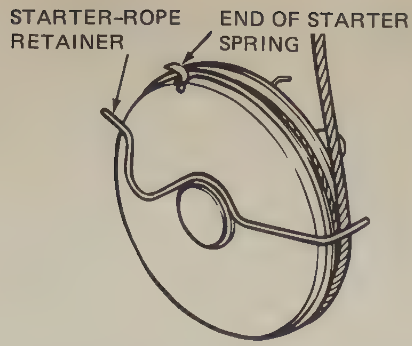


FIG. 24-25 When installed, the end of the starter spring hooks over the edge of the cover slot. (*Evinrude Motors Division of Outboard Marine Corporation*)

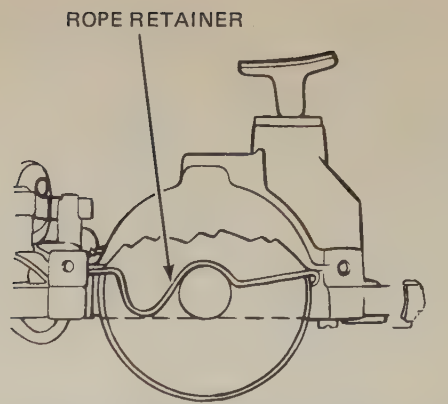


FIG. 24-27 Starter-rope retainer will lock in place when the starter is properly positioned. (*Evinrude Motors Division of Outboard Marine Corporation*)

retainer will lock into place as shown in Fig. 24-27 when the starter is positioned correctly.

Install and tighten the starter mounting bolt. Completely wind the rope around the starter pulley. Then turn the pulley an extra one to one and a half more turns for proper tension. Thread the rope through the handle, and fasten the handle to the rope.

○ 24-8 SERVICING WINDUP STARTERS

The windup starter is also called an impulse starter, self-starter, ratchet starter, speed starter, and other names. It uses a ratchet and pawl, or dog, mechanism to wind up and hold the tension of an internal spring. When the spring is released, it overcomes engine compression and friction to crank the engine. The ratchet is usually rotated directly through gearing by a windup handle. The spring is released by an external lever or control knob. Two types of windup starters are shown in Fig. 24-28.

Before beginning to work on a windup starter, always make sure the starter spring is fully unwound. Wind the spring several turns with the handle. Then trip the release lever or operate the control knob and let the spring unwind. If the spring does not unwind, on some models you can release the spring tension by taking off the handle, as shown in Fig. 24-29. Hold the handle with one hand, and remove the Phillips-head screw holding the handle to the starter.

CAUTION: Never attempt to work on a windup starter without releasing the spring tension. The spring is very strong and could cause serious injury if it should pop out of the starter during disassembly.

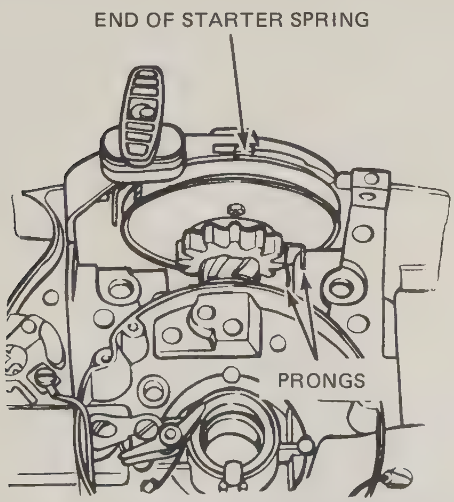


FIG. 24-26 Proper position of the end of the starter spring. (*Evinrude Motors Division of Outboard Marine Corporation*)

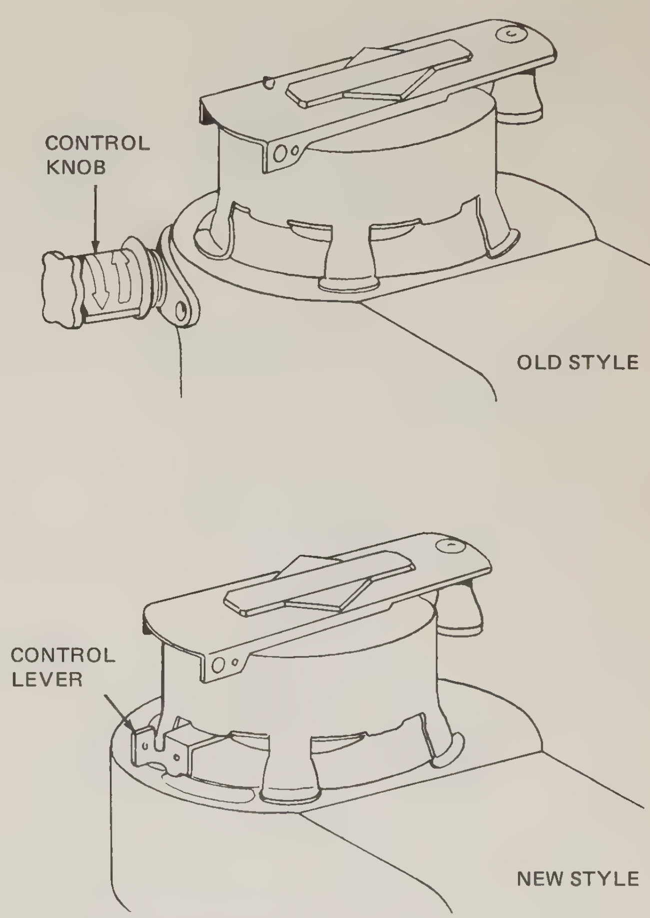


FIG. 24-28 (Top) Old-style windup starter with control knob. (Bottom) New-style windup starter with control lever. (*Briggs & Stratton Corporation*)

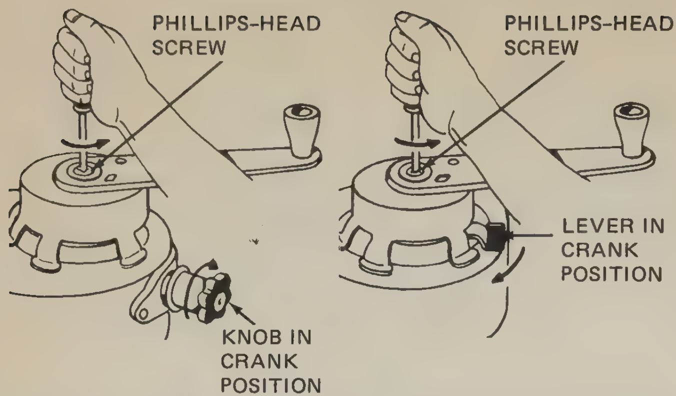


FIG. 24-29 Releasing the windup spring by removing the Phillips-head screw. Hold the handle with one hand while removing the screw.

If the starter does not crank the engine, the spring is broken or the starter clutch balls are not engaging. Put the control knob or release lever in position for START, and crank the handle 10 turns clockwise. While turning the crank handle, watch the starter clutch ratchet. The clutch ratchet is shown in Fig. 24-30. If the ratchet does not move, the spring is broken. If the ratchet moves, it is the ratchet that needs servicing.

Some windup starters are disassembled from the drive end. Others are disassembled from the handle end. If the handle is riveted or welded to the shaft, remove the drive mechanism first. The drive mechanism and retainer screws are similar to those on rope-rewind starters, but heavier. If necessary, remove the drive mechanism for repair. Remove the mainspring assembly, with its retainer.

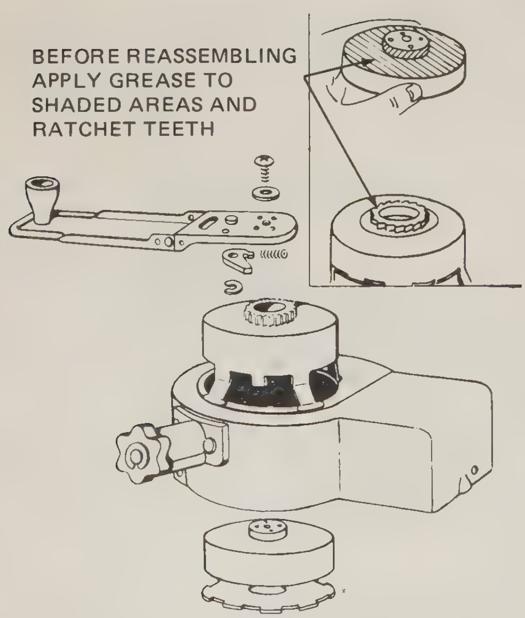


FIG. 24-30 Partially disassembled windup starter. (*Briggs & Stratton Corporation*)

CAUTION: Do not remove the spring from the retainer unless the service manual for the engine you are working on specifically says to do it and tells you how. These springs are very strong and can hurt you if they are released improperly!

When disassembling the drive mechanism, observe carefully the location and position of all parts so you can correctly put the mechanism back together. Inspect the housing and operating parts for cracks, worn gear teeth or ratchet, and broken or bent pawls. Watch for small parts such as springs, washers, and spacers. Clean all parts and lubricate all moving surfaces with engine oil.

If you install a new spring, be sure to destroy the old spring so that no one will get hurt tampering with it. The best way is to heat the old spring with a torch. This removes the temper and tension in the spring.

On reassembly, make sure you put all parts back into their proper places. Reinstall the starter on the engine, and check it for proper operation.

○ 24-9 SERVICING ELECTRIC STARTERS In this part of the chapter, we cover in detail the troubleshooting and service of electric starters used on small engines. There are two general types of electric starters: 12-volt and 120-volt. If the engine has a 12-volt starter, it probably has a charging system. The 12-volt starter needs a 12-volt storage battery. To keep the battery charged, a generator or an alternator is required. You have already learned about batteries and how to test and service them in previous chapters. Charging systems are covered in later chapters. If a 120-volt alternating-current starter is used, then a charging system is not required, although the engine may also have this equipment.

○ 24-10 TROUBLESHOOTING 12-VOLT STARTERS The most common problem you will encounter with starters is a starter that cranks the engine very slowly or does not crank it at all. In such a case, you can usually pinpoint the problem by turning on the lights (if provided) and then operating (or attempting to operate) the starter. Many engines equipped with 12-volt starters also have lights. Under normal conditions the battery voltage drops and the lights dim slightly as the engine is cranked. However, in the case of trouble, the lights may do one of the following:

1. Stay bright with no cranking action
2. Dim slightly with no cranking action
3. Dim considerably with no cranking action
4. Go out with no cranking action
5. Not come on at all

TABLE 24-1 12-VOLT STARTER TROUBLESHOOTING CHART

Condition	Possible Cause	Check or Correction
1. No cranking, no lights	a. Battery dead	Recharge or replace battery
	b. Open circuit	Clean and tighten connections; replace wiring
2. No cranking, lights go out	a. Poor connection, probably at battery	Clean cable clamp and terminal; tighten clamp
3. No cranking, lights dim slightly	a. Pinion (Bendix) not engaging	Clean pinion and sleeve; replace damaged parts
	b. Excessive resistance or open circuit in starter	Clean commutator; replace brushes; repair poor connections
4. No cranking, lights dim heavily	a. Battery weak	Check and recharge or replace battery
	b. Very low temperature	Make sure battery is fully charged and engine, wiring circuit, and starter are OK
	c. Pinion (Bendix) jammed	Free pinion
	d. Frozen shaft bearing, direct short in starter	Repair starter
5. No cranking, lights stay bright	a. Open circuit in switch	Check switch contacts and connections
	b. Open in control circuit	Check solenoid, ignition switch, and connections
	c. Open circuit in starter	Check commutator, brushes, and connections
6. Engine cranks slowly but does not start	a. Battery run down	Check and recharge or replace battery
	b. Very low temperature	Make sure battery is fully charged and engine, wiring circuit, and starter are OK
	c. Starter defective	Test starter
	d. Undersized battery cables	Install cables of adequate size
	e. Mechanical trouble in engine	Check engine
	f. Operator may have run battery down	
7. Engine cranks at normal speed but does not start	a. Ignition system defective	Check ignition system
	b. Fuel system defective	Check fuel pump, line, choke, and carburetor
	c. Air leaks in intake manifold or carburetor	Tighten mounting; replace gasket as needed
	d. Engine defective	Check compression, valve timing, etc.
8. Solenoid plunger chatters	a. Hold-in winding of solenoid open	Replace solenoid
	b. Weak battery	Charge battery
9. Pinion disengages slowly after starting	a. Sticky solenoid plunger	Clean and free plunger
	b. Overrunning clutch sticks on armature shaft	Clean armature shaft and clutch sleeve
	c. Overrunning clutch defective	Replace clutch
	d. Shift-lever return spring weak	Install new spring

No Cranking, No Lights Look at the first entry in the troubleshooting chart: no cranking, no lights. This should tell you that there is no voltage at the starter or at the solenoid terminal. If there were voltage, the lighs would light. The possible causes include all factors or defects which would prevent current from reaching the starter: a dead battery, defective connections, or a bad battery cable. The cables can be checked by inspection and by probing the connections. Look carefully for such things as corrosion and breaks in the cables. The battery can be checked with a voltmeter, a test lamp, or a hydrometer. Go back to Chapter 22 to find out about how to check batteries.

No Cranking, Lights Go Out If the lights come on when the light switch is turned on and if they go off when the starter circuit is closed, there probably is a bad connection between the starter and the battery. The bad connection is probably at one of the battery terminals. A poor connection, in effect, will not allow very much current to get through. There will be enough for the lights. But when the starter circuit is closed, most of the current that does get through then flows through the starter. This is because the electrical resistance of the starter is much lower than the resistance of the lights. However, there will be insufficient current to operate the starter.

You can often tell whether or not there is a bad connection at a battery terminal by keeping the starter circuit closed for a few seconds while watching the battery terminal connections. If there is a bad connection, heat will develop. You can feel this heat by touching the cable clamp. Sometimes there is so much heat that the connection starts to smoke. Moving the cable clamp around on the terminal a little may improve the connection enough to get the engine started. However, the remedy is to remove the cable clamp, clean the clamp and terminals, and install the clamp tightly.

You can find almost any bad connection in a circuit through which current is flowing by checking the voltage drop across the connection. This procedure is described later in this chapter.

No Cranking, Lights Dim Slightly If the lights dim when the starter circuit is closed, it may help to try to determine whether the lights dim only slightly or dim considerably. If the lights dim only slightly with no cranking action, it could be that there is excessive resistance or a partial *open* in the starter. This condition would prevent all but a small amount of current from flowing. No cranking and only slight dimming of the lights would result. If slight dimming is accompanied by the sound of a running electric motor, it is possible that the drive pinion (on the Bendix-type drive only) is not engaging. When this happens, the motor runs free without cranking the engine. The Bendix pinion might fail to engage because it is stuck on the sleeve. This could be due to dirt or gum or possibly to battered threads that prevent movement on the sleeve. If the slight dimming is accompanied by the sound of pinion engagement without cranking action, the starter solenoid (on overrunning-clutch drives) is producing pinion engagement but there is an opening in the starter that is preventing cranking action.

No Cranking, Lights Dim Heavily If the lights dim considerably without cranking action, there could be mechanical trouble in the engine, the battery could be run down, the temperatures might be very low, or there could be trouble in the starter itself. A run-down battery is the most common cause. The battery should be checked and recharged or replaced as necessary. At very low temperatures, when the engine oil is stiff and cranking is hard, the battery is subjected to a much heavier load. At the same time, a cold battery is much less able to maintain voltage under a heavy load. As a result, during cranking and very low temperatures, battery voltage will drop considerably and lights will become very dim. The cold can be so severe that the starter is unable to crank the engine at all.

If the pinion (Bendix type) jams in the flywheel or if there is trouble in the starter (frozen shaft bearings or a direct short, for example), the starter will draw a very high current without any cranking taking place. A jammed Bendix pinion may be replaced either by loosening the starter mounting bolts or by rocking the flywheel back and forth. Internal damage requires removal of the starter so that it can be overhauled.

Keep in mind that the operator may run the battery down in a vain attempt to start the engine. Then there is no cranking action when you test the starter, even though the battery may still be in good enough condition to light the lights. In such a case, the cause of failure to start is not in the battery or starter, but possibly in the ignition system, fuel system, or engine. Always question your customer to find out if the battery was run down trying to start the engine.

No Cranking, Lights Stay Bright If the lights stay bright as the starter circuit is closed and no cranking action takes place, it means there is no current flowing from the battery to the starter. The tests to be made to locate the open circuit differ according to the type of starting system.

On some engines, such as garden tractors and outboard engines, there is a safety interlock that prevents starting unless the selector lever is in neutral or park position. On such applications, be sure that the selector lever is in the proper position and that the safety switch and interlock circuit are in normal condition before proceeding.

Then, find out if the control system is doing its job by going through the procedure that should produce starter action. Move the gearshift lever to NEUTRAL or PARK, or depress the clutch pedal and turn the ignition switch to START, according to the normal starting method. One of two things will happen: (1) The solenoid or relay will not operate; or (2) the solenoid or relay will operate, but the starter motor will not. In either case, the problem should be checked further, as follows:

Relay or solenoid does not operate: This means that the current is not getting to or through the relay or solenoid. One of the various control devices is not doing its job. Before proceeding any further, make sure that the starter will operate. Momentarily connect a heavy jumper cable across the two main termi-

nals of the solenoid or relay. Touch the nuts, not the screws, to avoid burning the threads. On some relays and solenoids, this same test may be made by operating the relay or solenoid by hand. If the starter operates, look for trouble in the control system.

Relay or solenoid operates, but starter does not: This indicates that there is an open circuit in the relay, solenoid, or starter. Usually, the trouble will be found in the starter. Take the cover band off if the starter is equipped with one, and check the brushes and commutator. Further starter servicing will be discussed later.

Engine Cranks but Does Not Start If the starter turns the crankshaft slowly but the engine does not start, there are several conditions to consider. The battery may be run down, the temperature may be so low as to cause cranking difficulty, the starter may be defective, undersize cables may have been installed, or there may be mechanical trouble in the engine. It is also possible that the operator has run the battery down trying to start the engine. In this case, the starter may crank normally with a fully charged battery, but the engine will not start because of trouble in the ignition system or fuel system or because of abnormal conditions in the engine.

Engine Cranks at Normal Speed but Does Not Start Normal cranking but failure to start is another important trouble symptom. This is not a starter problem. It is usually caused by trouble in the ignition or carburetion system. Troubleshooting these systems is discussed in other chapters.

Chattering Solenoid Plunger A chattering solenoid is one in which the plunger is alternately pulled in and released. The motion of the plunger makes a chattering noise.

When properly energized, the solenoid engages the pinion and then closes the starter switch contacts. An open-circuited hold-in winding in the solenoid or magnetic switch will cause the plunger to pull in and release repeatedly when the control circuit is closed. With this defect, the pull-in winding pulls the plunger in and closes the circuit between the battery and the starter. But as this happens, the switch contacts short out the pull-in winding. Since the hold-in winding is then not operative, there is nothing to keep the plunger in, and the plunger is released. The pull-in winding is again energized, and it pulls the plunger in once more. Chattering results, as the plunger moves in and out of the solenoid or magnetic switch quite rapidly, and no cranking takes place.

Chattering may also be due to a weak battery or to excessive resistance in the starter control circuit. With either of these conditions, the solenoid windings may not become fully energized.

Pinion Disengages Slowly after Starting Sometimes the pinion will not release readily after the engine starts (overrunning-clutch drive). Then, after the engine speed increases, the pinion may release with a loud "zooming" sound. The overspeeding of the starter armature causes this sound. Such overspeeding may result in thrown armature windings and complete destruction of the starter.

The possible causes of this condition are a sticky solenoid plunger, an overrunning clutch sticking on the armature shaft, a defective overrunning clutch that will not allow the pinion to normally overrun the shaft, or a weak shift-lever return spring. If slow disengagement is noted, prompt measures to eliminate this trouble should be taken before the armature is ruined by thrown windings. Operate the shift lever by hand to see if it is binding or if the spring is weak. Remove the starter if necessary to check the freeness of the clutch on the armature shaft, and the clutch operation.

○ 24-11 CHECKING 12-VOLT STARTERS

Two general types of drives are used with battery-powered starters for small engines. One type is a mechanical drive, such as the Bendix drive (Fig. 23-19), the overrunning clutch drive (Fig. 23-18), or the rubber-compression drive (Fig. 23-20). The other type is a belt drive, as shown in Fig. 24-31, which is a cutaway view of a 12-volt starter mounted on an engine. The belt-drive starter is used with a belt clutch, either in the starter pulley or in the crankshaft pulley. Because of the action of the belt clutch, the belt can drive only one way, and that is from the starter to the engine. When the engine starts and attempts to backdrive the starter, the clutch disengages it.

Regardless of type, no regular service is required on the starter drive. However, belt-drive starters must have the drive belt checked and adjusted periodically. To do this, remove the belt guard. Check the condition of the belt and its deflection, as shown in

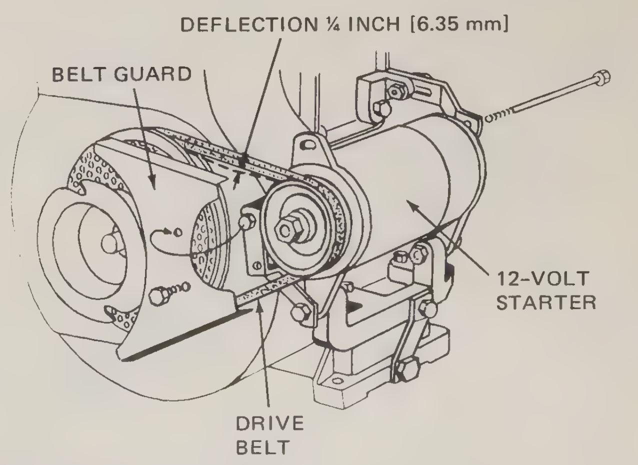


FIG. 24-31 A 12-volt starter that uses belt drive. (*Briggs & Stratton Corporation*)

FIG. 24-32 Conditions to look for when checking drive belts. (*Gates Rubber Company*)

Fig. 24-31. Various conditions of the drive belt that require its replacement are shown in Fig. 24-32.

Most electric starters are prelubricated and require no further lubrication during normal service. About the only trouble that can occur inside the starter results from worn brushes or commutator. Sometimes starters are damaged by overloading that causes overheating. Such overloading can result from excessively long cranking periods. An electric starter should not be used for longer than about 10 seconds at a time. If the engine does not start within this time, the starter should be released. Allow it to cool for one minute or longer before attempting to restart. Continuous cranking will overheat and damage the starter.

Checking the Electrical Connections When an engine cranks slowly, or fails to crank, and low temperature is not to blame, check the battery. Battery service is covered in Chap. 22. Then look at the cables and connections. If cables are frayed and connections are bad, not enough current can get through to produce normal cranking.

Checking the Starter Control On systems using a starter switch or a solenoid, bypass the switch or solenoid by connecting a heavy jumper wire to the two terminals. If the starter works, the trouble is in the switch or solenoid.

Inspecting the Starter Motor If everything outside of the starter looks satisfactory, then check the starter brushes and commutator. Some starters have a cover band which can be removed. This type of starter is shown in Fig. 24-33. On other starters, such as shown in Fig. 23-18, you must remove the end frame or cap assembly. This is done by removing the two through bolts so that the cap can be slipped off part of the way. To take the cap completely off, take the insulated brush out of the brush holder. This is done by lifting the spring and gently pulling the brush out.

Examining the Brushes and Commutator If the brushes are worn down (Fig. 24-34), they must be replaced. If the commutator is worn or rough, it should be cleaned with fine sandpaper or a brush-seating stone (Fig. 24-35). Never use emery cloth to clean the commutator. Some manufacturers supply brush replacement kits. The grounded brush lead may be riveted to the end cap. The rivet must be drilled out so the new brush lead can be riveted into place. The insulated brush is connected to the field lead and must be unsoldered before removal. Then the new brush lead is soldered to the field lead. Rosin-core solder must be used when soldering electrical connections.

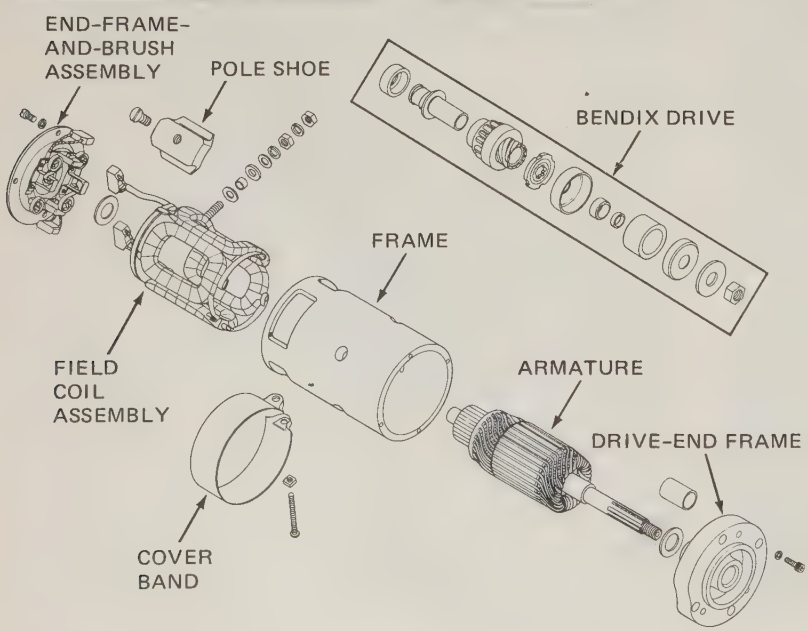


FIG. 24-33 Disassembled view of an electric starter with a Bendix drive. (*Kohler Company*)

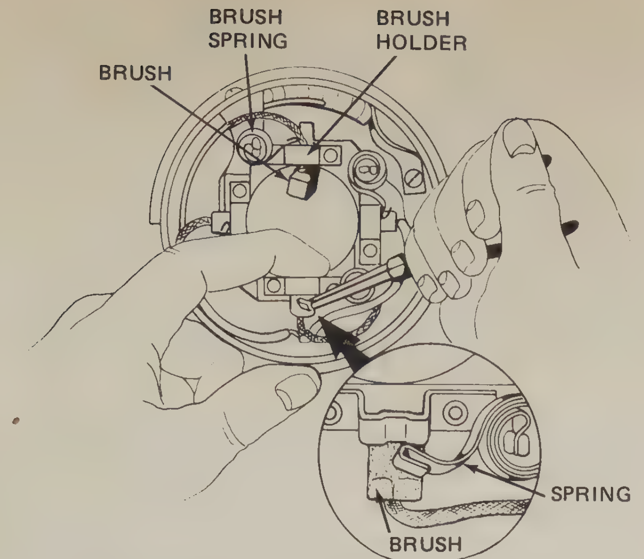


FIG. 24-34 Checking the brushes for wear. (*Briggs & Stratton Corporation*)

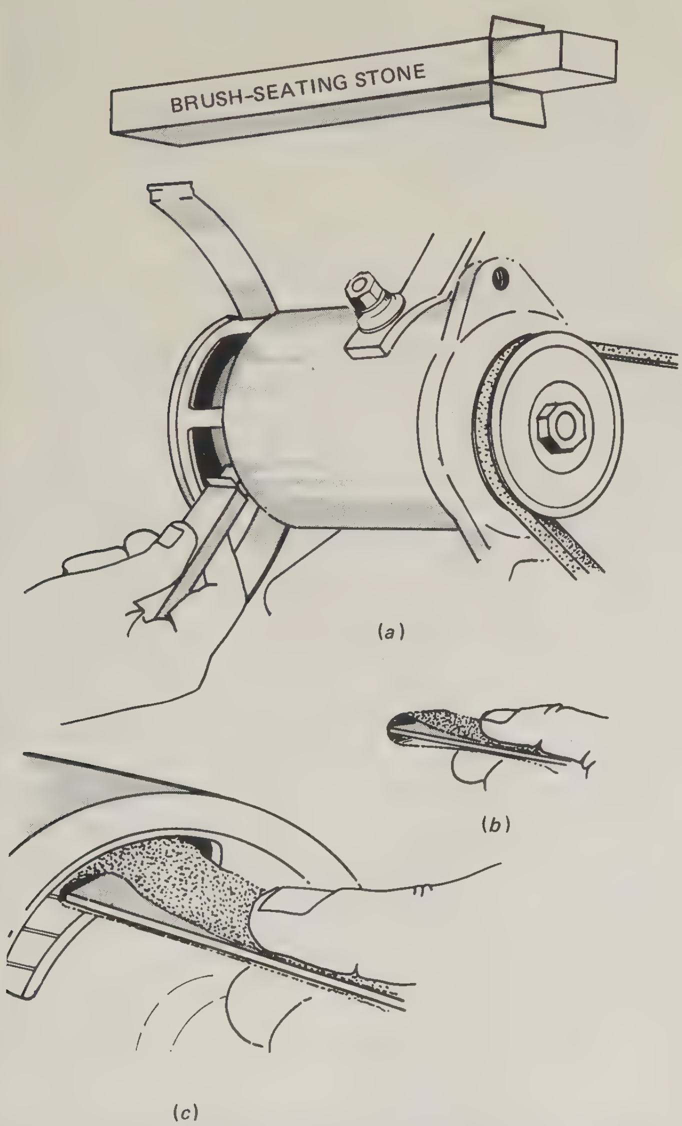


FIG. 24-35 Cleaning commutator with a brush-seating stone (*a*) or sandpaper (*b*) and (*c*).

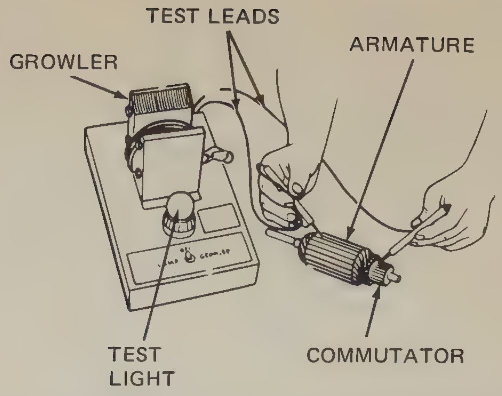


FIG. 24-36 Checking an armature for grounds using a test light. (*Outboard Marine Corporation*)

Some manufacturers state that cleaning of the commutator and replacement of brushes are the only services that should be attempted. If there are other troubles in the starter, a new starter should be installed. Complete disassembly of some starters is not recommended.

○ 24-12 STARTER-MOTOR SERVICE Many manufacturers supply detailed instructions and illustrations, such as shown in Fig. 24-33, to help you rebuild starter motors. When the starter is disassembled, the armature, field-frame assembly, and brush holders should be checked with a test light for shorts and grounds. Using a test light on a growler to check for grounds in the armature is shown in Fig. 24-36. If the armature is in good condition, place it in the growler and check for shorts, as shown in Fig. 24-37. If the commutator on the armature is worn, burned, or out-of-round, place the armature in an armature lathe, as shown in Fig. 24-38. Remove only enough metal to clean the commutator and restore it to a round condition. Then the mica should be undercut, as shown in Fig. 24-39. Your instructor will show you how to perform these operations in the shop.

If you are working on a small starter and have removed only the end cap to check the commutator

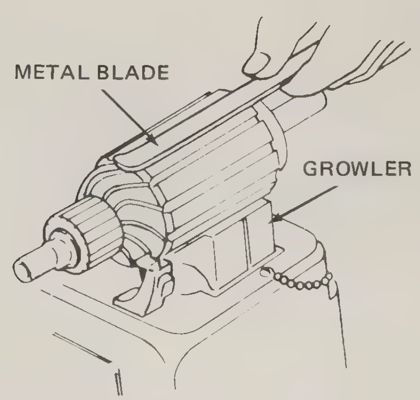


FIG. 24-37 Testing an armature for short circuits on a growler. (*Delco-Remy Division of General Motors Corporation*)

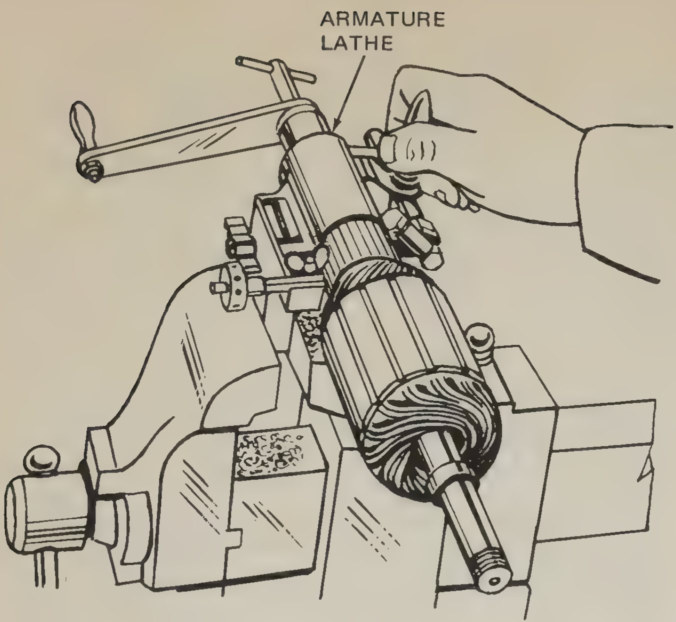


FIG. 24-38 Using a vise-mounted armature lathe to refinish the commutator bars.

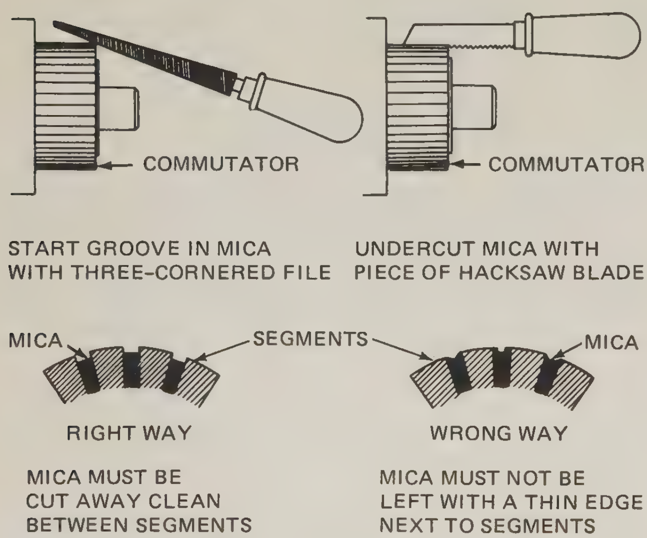


FIG. 24-39 Undercutting the mica on the commutator.

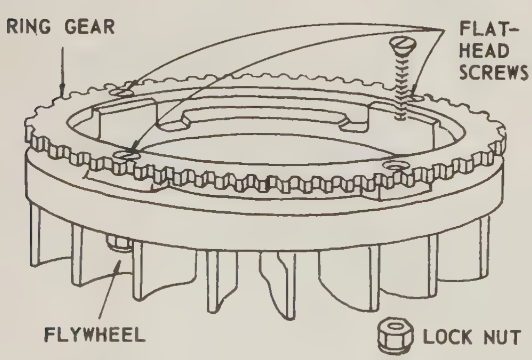


FIG. 24-40 Method of replacing ring gear in one model of small engine. The old ring gear is removed by drilling out the attaching rivets, and then the new ring gear is attached with screws and locknuts. (*Briggs & Stratton Corporation*)

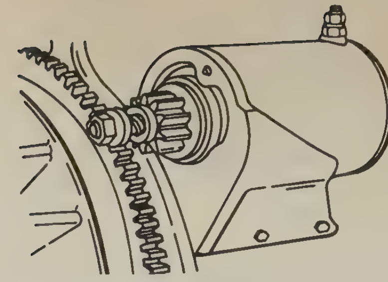


FIG. 24-41 Relationship of ring gear to pinion gear of Bendix drive. Incorrect alignment will cause poor meshing and rapid tooth wear. (*Kohler Company*)

and brushes, lubricate the bushing and armature shaft before putting the end cap back on. Coat the bushing in the end cap and the end of the armature shaft lightly with SAE 10 oil before installing the end cap. Do not put on too much oil or it will get onto the commutator and brushes and cause trouble.

When putting the end cap back on, make sure the brushes are lifted so they will allow the commutator to pass under them. This can be done by pulling up on the brush springs with needle-nose pliers as shown in Fig. 24-34. After the cap is partly on, let the springs down so the brushes will rest on the commutator. The end cap can then be pushed on into place and then through bolts installed to complete the assembly.

○ 24-13 CHECKING THE BENDIX DRIVE To inspect the Bendix drive, remove the starter from the engine. If the drive pinion or splined sleeve is damaged, the drive must be replaced. Do not lubricate the Bendix drive. This can cause it to stick.

While the starter is off, check the ring gear on the engine flywheel. If the teeth are battered or broken, the ring gear should be replaced. One method of replacing the ring gear is shown in Fig. 24-40. This ring gear is attached with rivets on the original assembly. The rivets must be drilled out as follows: Mark the centers of the rivets with a center punch. Then drill out the rivets with a $^3/_{16}$-inch drill. Clean the holes after drilling out the rivets. Then attach the new ring gear with the four screws and locknuts that are supplied in the ring-gear kit.

When reinstalling the starter on the engine, use the special mounting bolts and lockwashers from the original installation. These bolts provide the proper alignment of the drive gear to the ring gear, as shown in Fig. 24-41. Incorrect alignment can cause gear clash and damage to the gears.

REVIEW QUESTIONS

1. What are the four types of mechanical starters for small engines?
2. If the starter will crank the engine, is the starter the cause of a starting problem?

3. What types of starters require the rope to be replaced periodically?
4. What type of starters have powerful springs in them?
5. Why must eye protection be worn when you are working on certain types of starters?
6. What is a vertical-pull starter?
7. If a rope-rewind does not rewind the rope, what probably has happened?
8. If a windup starter unwinds as soon as you release the windup handle, what probably has happened?
9. On belt-drive starters, why is it necessary to check the belt regularly?
10. What are the three basic starting-motor problems?
11. A starting motor does not turn over: What are the five possible causes of the trouble?
12. What is the checking procedure if the engine cranks slowly but does not start?
13. What is the most common cause of burned commutator bars?
14. Explain how to turn a commutator.
15. Explain how to test an armature on a growler.
16. Explain how to check the brushes.

SELF PROJECTS

1. Make a list of the tests to be made if the starting motor does not turn over when starting is attempted.
2. List the conditions that might cause slow cranking.
3. If you can find defective starting motor parts, examine them and decide what has caused the defects. Burned commutator bars, grounded field windings, loose conductor connections to the commutator bars, thrown armature windings, and bent armature shafts are samples. Write descriptions of the defects on tags, and attach the tags to the defective parts. This is the actual procedure used by the dealer to return defective parts to the factory under warranty.

25
Chapter

Ignition Systems

After studying this chapter, you should be able to:

1. **List the types of ignition system used on small engines**
2. **Explain the purpose of the ignition system, and describe the components in the system**
3. **Describe the construction and operation of a magneto ignition system**
4. **Describe the two circuits in the ignition system and explain how they work**
5. **Explain the difference between the breaker-point ignition system and the electronic breakerless ignition system, and describe how both systems work**
6. **Explain the difference between a breakerless ignition system and a capacitor-discharge ignition (CDI) system**
7. **Explain the purpose of the centrifugal- and vacuum-advance mechanisms in the distributor and how these mechanisms work**

○ 25-1 TYPES OF IGNITION SYSTEMS A considerable variety of ignition systems have been used with internal-combustion engines. There are two main categories: magneto ignition and battery ignition. The magneto ignition system is self-contained and needs no outside source of energy. However, the battery ignition system gets its energy from the lead-acid storage battery, which we covered in Chaps. 21 and 22.

There are certain variations of these basic ignition systems, which we cover in this chapter. The earlier magneto ignition systems use contact points (also called breaker points, because they break a circuit). A later type, called electronic ignition (EI), does not use contact points. Instead, this breakerless magneto ignition system uses electronic devices which do the same job as contact points. Another type of ignition system is the capacitor-discharge ignition (CDI) system. It stores energy in a large capacitor, instead of in a coil as do the other ignition systems.

Although some small engines use battery ignition systems, most use some type of magneto ignition system.

○ 25-2 PURPOSE OF THE IGNITION SYSTEM The ignition system supplies high-voltage surges (of up to 35,000 volts in some systems) of current to the spark plugs in the engine cylinders. These surges produce electric sparks at the spark-plug gaps. The sparks ignite, or set fire to, the compressed air-fuel mixture in the cylinders. When the engine is idling, the sparks are timed to appear at the plug gap just as the piston approaches top dead center at the end of compressing the air-fuel mixture. On many engines, there is an advance mechanism that moves the spark ahead, or advances it, when the engine is running at higher speeds. This gives the mixture enough time to burn and deliver its power to the piston.

Variable-speed engines such as those used in automobiles, motorcycles, and many small-engine applications have ignition systems that do the following:

1. Produce sparks at the spark-plug gaps to ignite the compressed air-fuel mixture in the cylinders.
2. Advance the timing of the sparks as the engine speed increases. The sparks are moved ahead so the air-fuel mixture is ignited earlier in the cycle.
3. Advance the timing when the engine is running at part throttle, because there is less mixture in the cylinders and it burns slower.

Small engines that run at constant speed do not have features 2 and 3. For example, a lawn mower that runs at a steady speed of 3000 rpm does not have a speed and part-throttle advance mechanism because it does not need it.

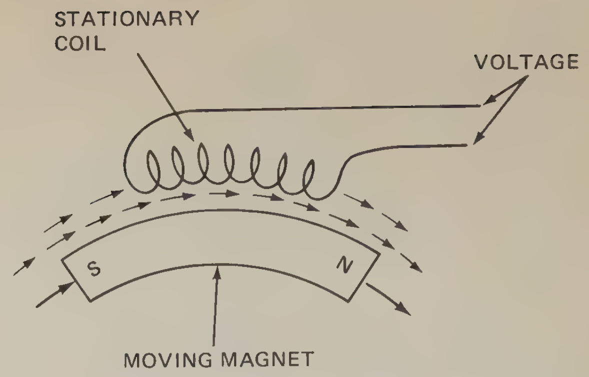


FIG. 25-1 When a magnet moves past a stationary coil of wire, a voltage is induced in the coil.

MAGNETO IGNITION SYSTEMS

○ 25-3 PRINCIPLES OF MAGNETO IGNITION A magneto is an engine-driven device that generates its own primary current, transforms that current into high-voltage surges, and delivers them to the proper spark plugs. Some magnetos are built into the engine. Others are separate units that are installed on the outside of the engine. The internal type is usually called a flywheel magneto, because the engine flywheel is an integral part of the magneto. Magnetos can be classified in another way. They may be the type with contact or breaker points or the type that does not use contact points. But regardless of all these differences, all magnetos work on the same basic principle. The principle is that movement of a magnetic field past stationary conductors induces voltage and a current flow in the conductors.

Figure 25-1 illustrates the principle. A stationary coil of wire is positioned above a moving magnet. As the magnet moves past the coil, it carries a magnetic field through the coil. This produces a voltage in the coil. If the coil is connected to an electric device, this voltage would cause current to flow.

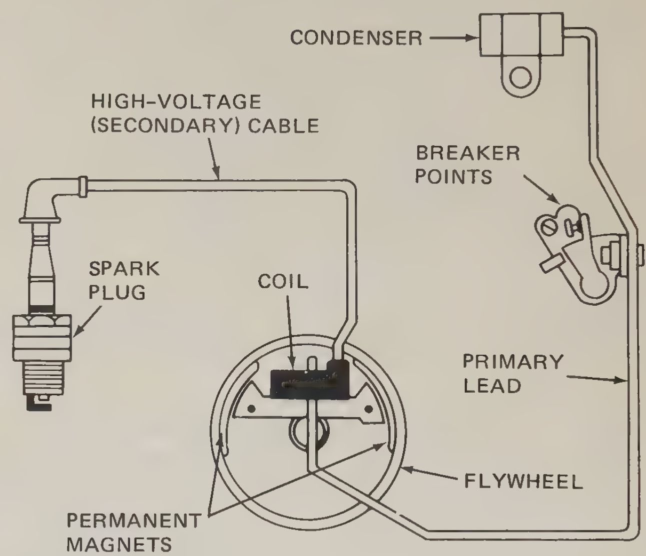


FIG. 25-2 Typical flywheel magneto ignition system. (*Kohler Company*)

○ 25-4 PRINCIPLES OF A CONTACT-POINT FLYWHEEL MAGNETO Figure 25-2 shows schematically a flywheel magneto using the principle illustrated in Fig. 25-1. The flywheel itself is shown separately in Fig. 25-3. Figure 25-4 shows in cutaway view how the magneto fits into the engine.

The coil shown in Fig. 25-4 consists of two windings: a primary winding of a relatively few turns of heavy wire and a secondary winding of many turns of fine wire. The primary winding works part of the time, and the secondary winding works at another time, as explained later.

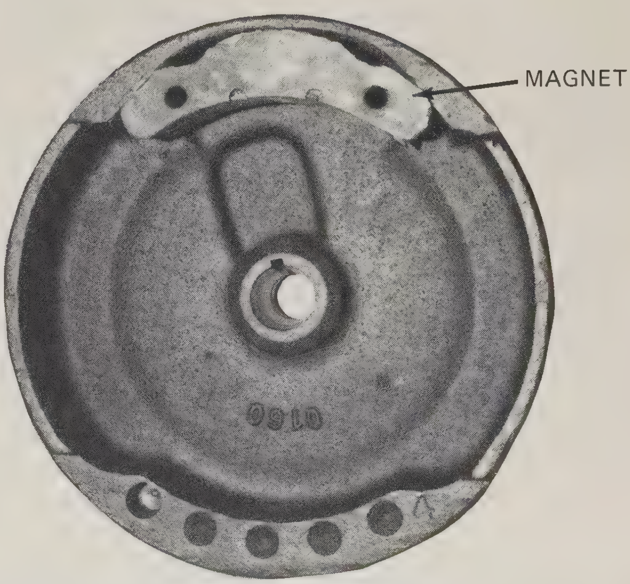


FIG. 25-3 Magnet mounted in the rim of the engine flywheel. (*Clinton Engine Corporation*)

Figure 25-5 is a wiring diagram of the primary circuit. It includes the coil of wire which is the primary winding. The magnets move past this primary winding when the flywheel rotates. Also included in the

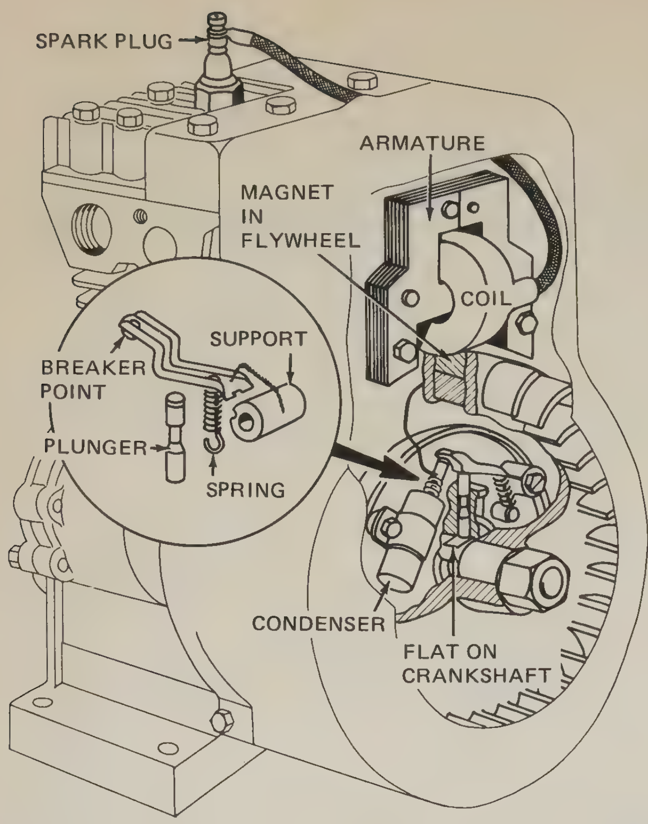


FIG. 25-4 Cutaway view of engine, showing location and construction of the magneto. (*Briggs & Stratton Corporation*)

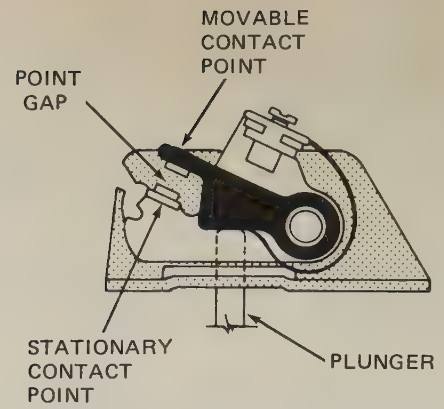


FIG. 25-6 Contact point set for a small engine. (*Kohler Company*)

circuit is a pair of breaker points, as shown in Fig. 25-6. One of these points is on a lever, or arm. The other point is stationary. One end of the arm rests on a plunger which rides on a cam on the crankshaft. This cam is round except for a flat spot. When the crankshaft and cam rotate, the breaker points remain closed all the time the plunger is riding on the flat spot. Then the flat spot moves out from under the plunger, and the round part of the cam moves in under the plunger. When this happens, the plunger is pushed up, and this causes the contact points to separate.

Now let us see how these actions can produce an electric spark. When the engine is running, the magnets are whirling past the coil primary winding. Voltage is induced and current flows in the coil when the breaker points are closed. This current causes a strong magnetic field to build up around the winding. When the round part of the cam comes around under the plunger and the breaker points separate, the current stops flowing. Now the magnetic field rapidly collapses.

The capacitor (also called a *condenser*) aids this rapid collapse of the magnetic field. The condenser contains two long strips of metal foil insulated from each other, as shown in Fig. 25-7. When the points start to separate, the current would continue to flow, causing a momentary arc between the points, if it were not for the capacitor. But for a moment the capacitor provides a place for this current to flow. It acts somewhat like a check spring and brings the current to a quick stop. This produces the rapid magnetic-field collapse.

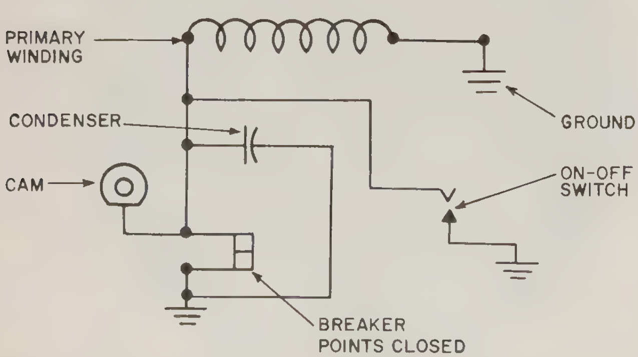


FIG. 25-5 Wiring diagram for magneto ignition with current flowing through the primary circuit. (*Lawn Boy Division of Outboard Marine Corporation*)

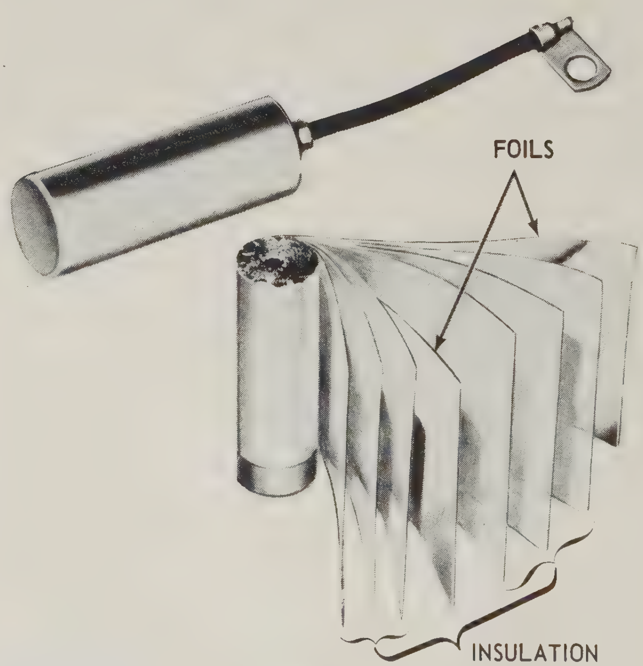


FIG. 25-7 Condenser assembled and with the winding partly unwound.

Surrounding the primary winding is a secondary winding made of many thousands of turns of a fine wire, as illustrated in Fig. 25-8. The magnetic field from the primary winding, in collapsing, moves rapidly through the secondary winding. Since this is a movement of a magnetic field through a conductor, a voltage is induced in the secondary winding. And, since there are many thousands of turns of wire in the secondary winding, a high voltage is induced.

The spark plug, shown in Fig. 25-9, is connected to the two ends of the secondary winding. One end is connected through the metal of the engine (called ground), and the other through a rubber-covered wire (called the high-voltage lead). The voltage in the secondary winding quickly goes up high enough to cause a powerful spark to jump the gap between the two spark-plug electrodes. One of these electrodes is connected to the metal shell of the plug which is screwed into the cylinder head of the engine. The other is insulated by a porcelain shell in which it is centered. The porcelain is breakable, just like glass. This is the reason that the center electrode must never be bent when the spark-plug gap is adjusted. Only the outer electrode should be bent. If the center electrode is bent, the porcelain probably will be broken and the plug will be ruined. This is also the reason that the plug must be removed and installed with care. Improper handling will also break the porcelain and ruin the plug.

Figure 25-10 shows, in end view, what happens before and after the contact points separate. Figure 25-11 is a top view of a typical magneto. Notice the arrangement of the coil, the contact points, and the condenser. The magnets are curved so that, as the flywheel rotates, they pass close to the coil. The magneto shown in Fig. 25-10 uses a cam that has a high spot or lobe instead of a flat spot (as in the magneto in Figs. 25-7 and 25-8). Also, the end of the movable contact-point arm rests on the cam so the arm moves when the lobe comes up under it. The result is the same. Part of the time the contact points are open. The rest of the time they are closed.

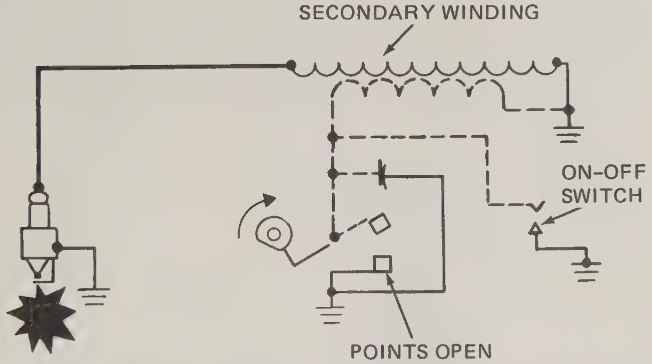


FIG. 25-8 Wiring diagram of a magneto ignition system with breaker points open. Current has stopped flowing in the primary circuit, and a high-voltage surge has been induced in the secondary circuit to produce a spark at the spark-plug gap in the cylinder. (*Lawn Boy Division of Outboard Marine Corporation*)

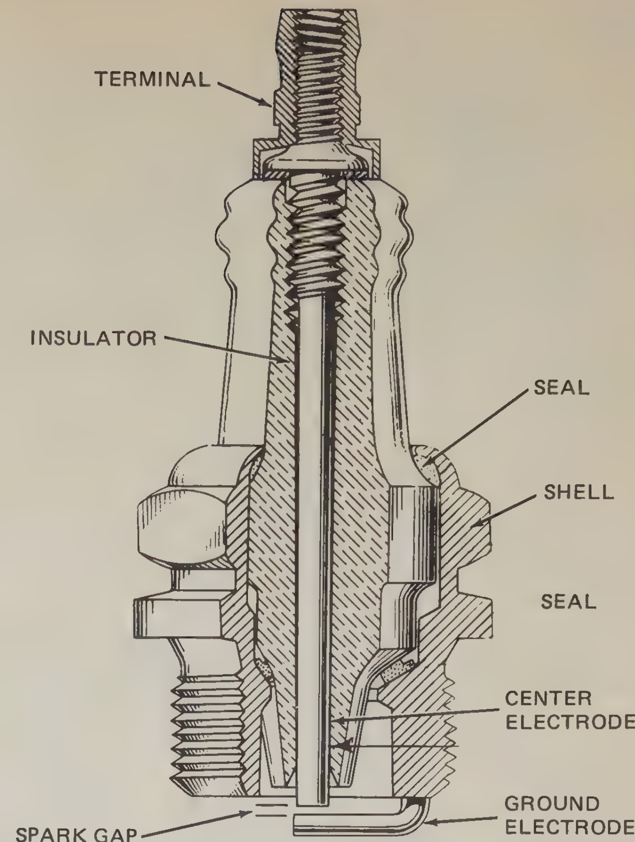


FIG. 25-9 Spark plug partly cut away to show construction.

When the points are closed, current is flowing through the primary circuit. When the points are open, the current stops. The magnetic field around the primary winding collapses, and this induces a high voltage in the secondary winding. When this happens, the high-voltage surge causes a spark at the spark-plug gap.

An ON-OFF switch is used on many ignition systems to turn the engine off. Figure 25-8 shows one type. When this switch is flipped so it is closed, it grounds the contact-point end of the primary winding. Now current continues to flow in the primary winding, and opening the points does not interrupt it. As a result, no sparks occur and the engine stops. The engine can also be stopped by a grounding blade located near the spark plug which can be bent by hand or foot to ground the insulated terminal of the plug, as shown in Fig. 25-12. When this happens, the current flows through the blade, and no spark occurs.

Figure 25-13 shows other types of stop switches. All work the same way. They ground the coil primary so that, even though current continues to flow in it, the magneto cannot produce a high voltage.

○ 25-5 EXTERNAL MAGNETO

Some engines have an externally mounted magneto, as shown in Fig. 25-14. The magneto rotor is driven through an

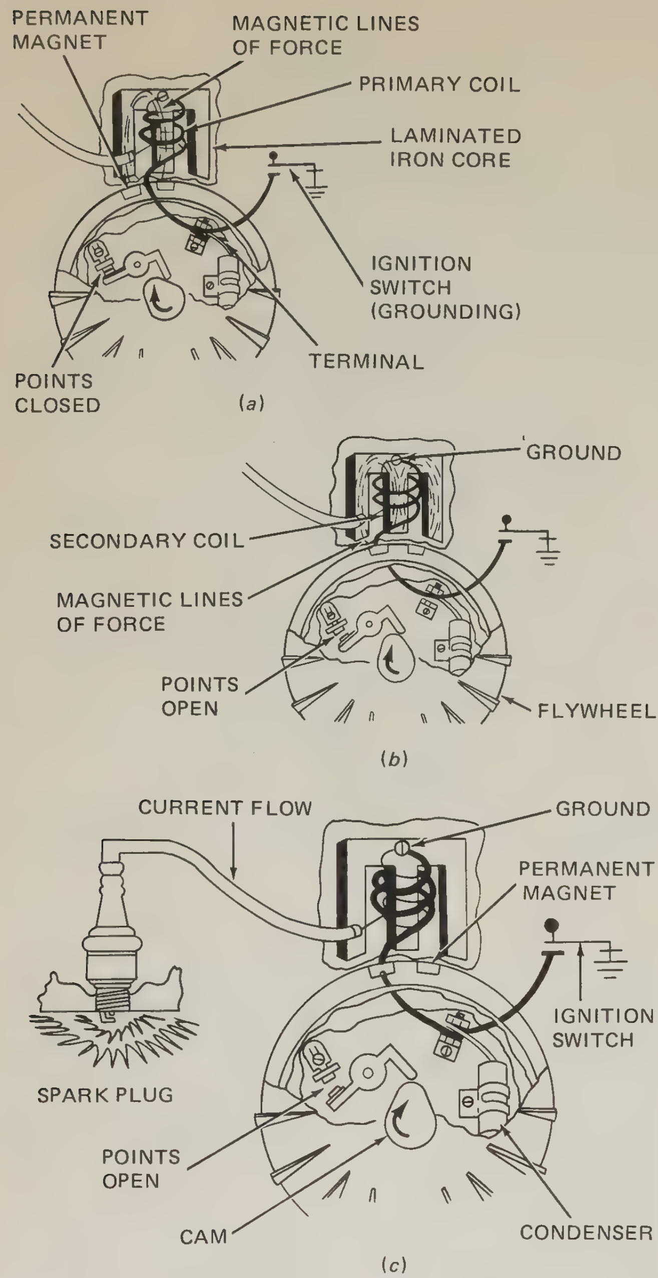


FIG. 25-10 Operation of the flywheel magneto (*a*) as energy builds up in the primary and (*b*) at the instant the points separate. (*c*) The induced high voltage produces the spark.

impulse coupling, which will be explained later. As the rotor spins, it produces a magnetic field in the laminated iron frame on which the primary and secondary coils are wound. Each half turn of the magnetic rotor causes a complete reversal of the magnetic field in the laminated iron frame. This, in turn, causes magnetic lines of force to build up and collapse through the primary and secondary windings. Therefore, a flow of current is induced in the primary winding all the time that the contact points are closed.

When the current flow is at its greatest, the breaker points are opened by the cam on the end of the rotor shaft. This stops the flow of current, and the magnetic

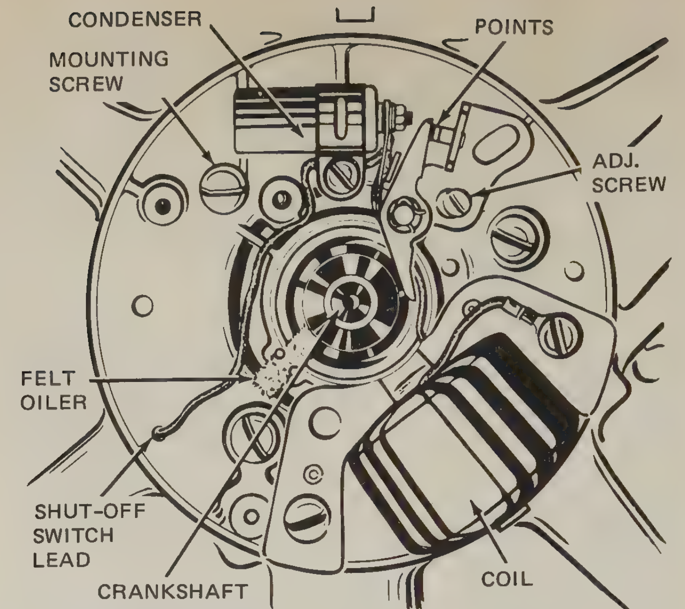


FIG. 25-11 Top view of the magneto. (*Lawn Boy Division of Outboard Marine Corporation*)

lines of force collapse very rapidly. The rapid movement of the lines of force through both the primary and secondary windings produces a high voltage in the secondary winding. This voltage is high enough to produce a strong spark at the spark-plug gap. The condenser does the same job here as in the other magneto ignition system previously discussed.

The impulse coupling (Fig. 25-15) through which the rotor shaft is driven is included to improve starting. It does two things: First, it retards the ignition timing for better starting during cranking. Second, it flips the magneto rotor at the proper moment so that the rotor spins very rapidly for a part turn and therefore produces a stronger spark. The faster the magnetic field from the magneto rotor moves through the laminated iron frame, the stronger the magnetic field induced in the iron frame becomes and the higher the voltage in the secondary winding goes. The impulse coupling produces this action through a delayed spring action. During cranking, spring tension builds up during a part turn of the coupling and then releases to spin the rotor ahead. The rotor turns part

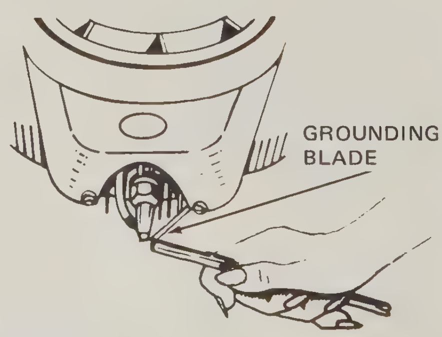


FIG. 25-12 Grounding blade near the spark plug used to stop the engine.

FIG. 25-13 A stop button or a stop switch may be used to shut down some engines. *(Kohler Company)*

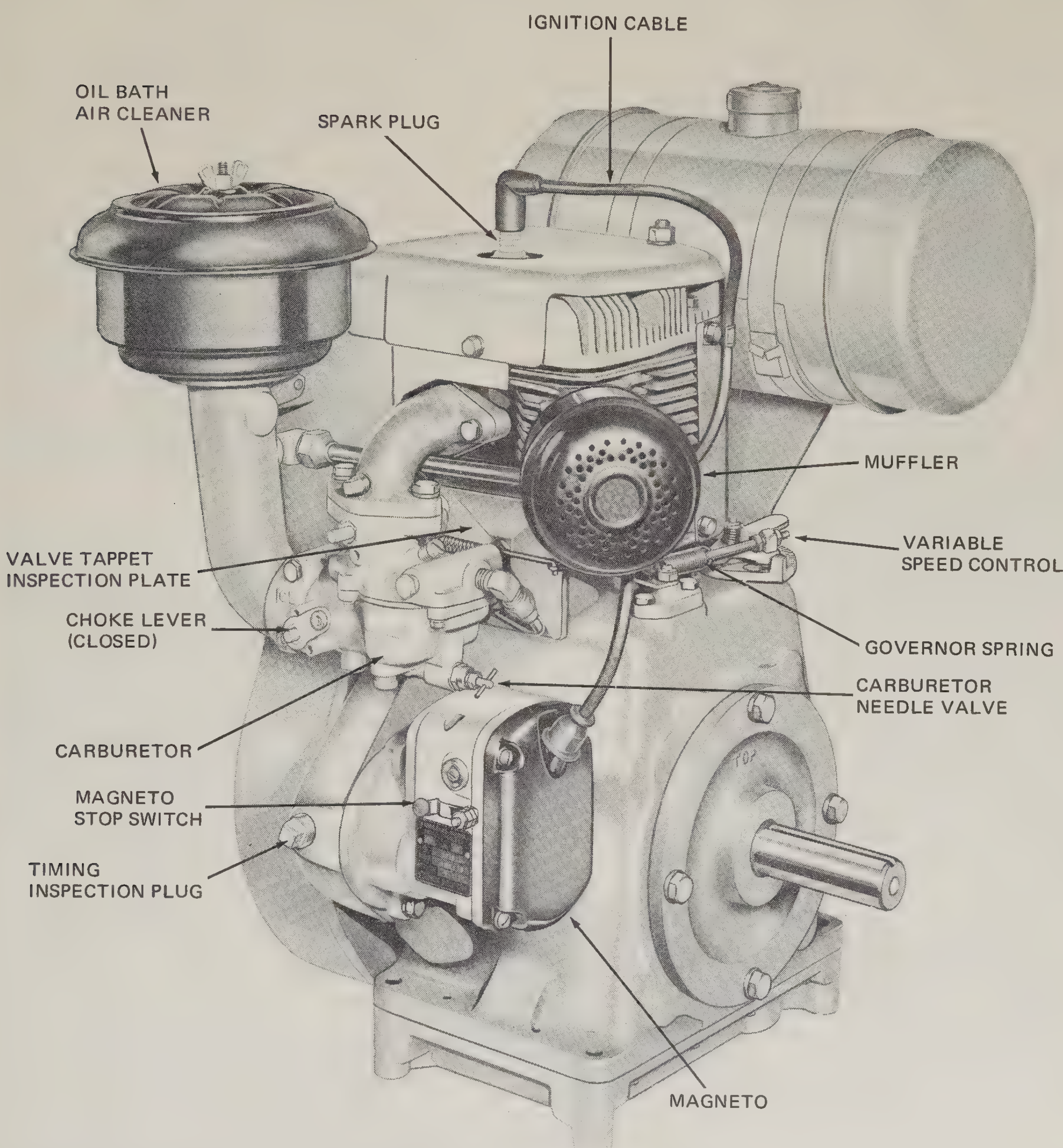


FIG. 25-14 An externally mounted magneto on a one-cylinder four-cycle engine. *(Wisconsin Motor Corporation)*

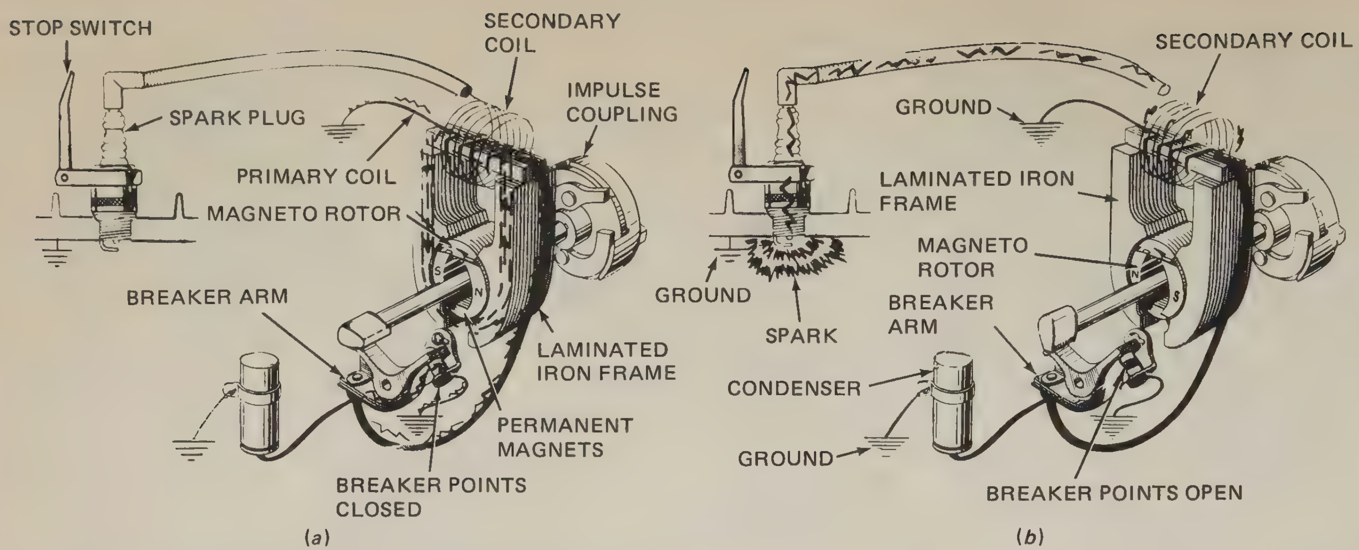


FIG. 25-15 Schematic view of an external-type magneto ignition system. (*a*) Breaker points closed. (*b*) Breaker points open.

way, stops momentarily until spring tension builds up again, and is once more flipped ahead. After the engine starts, the impulse coupling unlocks, owing to centrifugal action, so that it does not function. Now the rotor turns steadily in time with the engine.

○ 25-6 OTHER EXTERNAL MAGNETOS Figure 25-16 is a schematic view of a magneto for a four-cylinder two-cycle outboard engine. Let us see how a magneto can feed high-voltage surges to the four spark plugs in the four cylinders of the engine.

There are several special features on this magneto. In Fig. 25-16, notice that the magneto has two magnets and a rotor. The rotor is made up of iron strips which carry magnetism very well. When the rotor aligns with a pair of unlike magnetic poles, as shown in Fig. 25-16, the magnetic field is strongest. At this position, the points open. When the points open, the magnetic field collapses, producing the high voltage in the coil secondary winding.

This magneto has two sets of breaker points which are operating in parallel. They are mounted at a 90° angle to each other. The two sets operate alternately to make and break the primary circuit. The reason for using the two sets is that a single set could not operate fast enough to do the job at high engine speed. For example, at 4000 engine rpm, 16,000 high-voltage surges are needed each minute to fire the spark plugs. One set of points could not operate that fast. So the job is split between two sets.

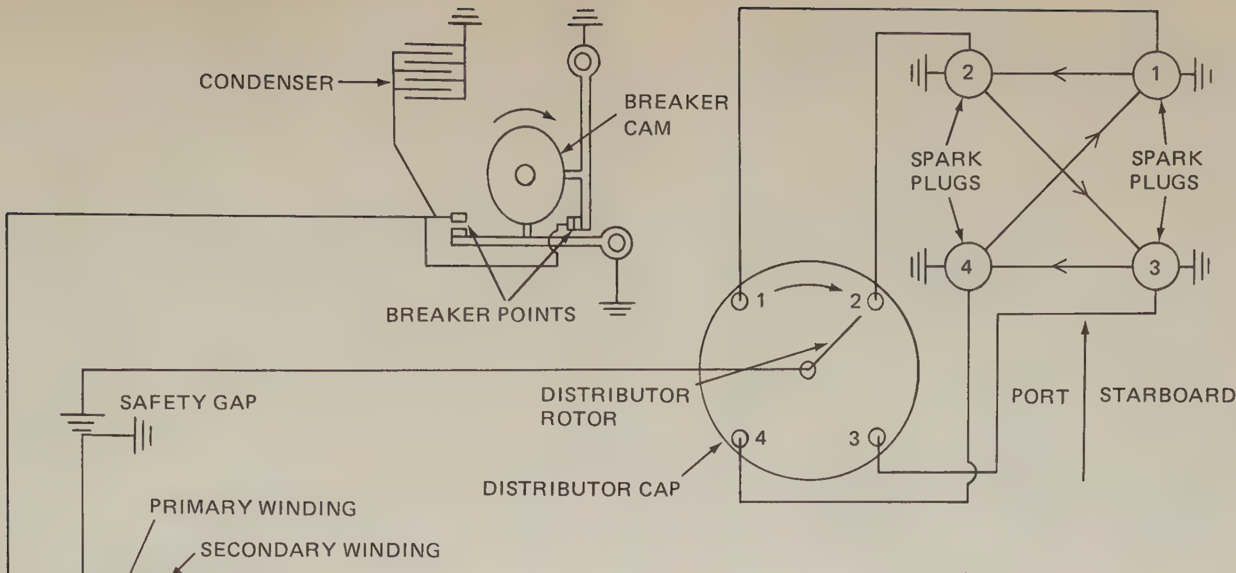
Notice also in Fig. 25-16 that the spark plugs are connected to the secondary winding through a distributor. The distributor has a rotor that moves past four terminals as it turns. The center of the rotor is connected to the secondary winding of the coil. As the rotor turns, it connects to the four spark plugs through the wiring. As a high-voltage surge is produced in the secondary winding, it is sent to the spark plug in the cylinder that is ready to fire.

○ 25-7 BREAKERLESS MAGNETO IGNITION SYSTEMS Today many small engines have magnetos without contact points. Instead, electronic devices take the place of contact points. These electronic devices have no moving parts. As a result, the ignition systems require less maintenance, because there are no contact points to wear and require adjustment and replacement. These electronic devices include diodes, which are one-way electric valves, and transistors, which are controlling devices that act like switches.

○ 25-8 DIODES AND TRANSISTORS In Chap. 20, we discussed electrons and explained that electric current is really electrons in motion. Keep that fact in mind as you study about diodes and transistors. Their action depends on electron movement and also on the absence of electrons.

When we talk about these electronic devices (diodes and transistors), we get into the *solid-state* world of *semiconductors*. *Solid state* means that the diodes and transistors are solid with no moving parts (except electrons). *Semiconductor* means a material that is halfway between a conductor and a nonconductor.

The *diode* is a one-way valve for electric current (Fig. 25-17). Current is allowed to pass through in one direction, but is blocked should it try to flow in the opposite direction. This control of the direction of current flow is the job of the rectifier in many electric circuits, and it is the job a diode can perform. Charging systems with alternators use diodes. Alternators produce alternating current (ac). The diodes change this to direct current (dc). Engine electrical systems require dc, so the diodes work with the alternator to produce dc. The diode is shown in wiring diagrams



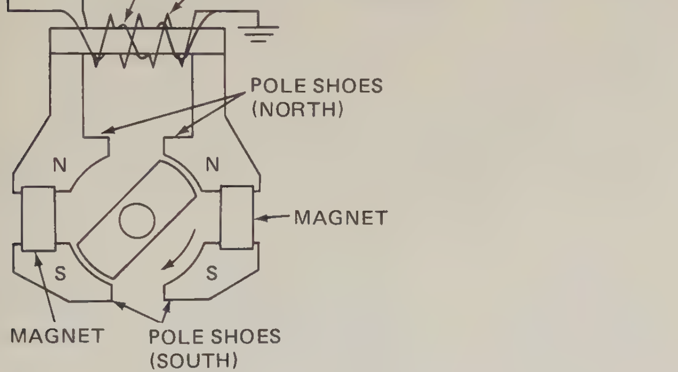


FIG. 25-16 Schematic diagram of the external magneto ignition system for a four-cylinder two-cycle outboard engine. (*Johnson Motors Division of Outboard Marine Corporation*)

as an arrow and a line perpendicular to the arrow (Fig. 25-17).

The *transistor* acts as an electric switch in which a small current flowing into one part can allow a large current to pass through a different part. In this way, a transistor acts like an amplifier. Figure 25-18 shows the way a transistor is represented in a wiring diagram. When no current flows to the base, no current can flow through the transistor between the emitter and the collector. But when a small current flows to the base, a large current can flow between the emitter and the collector. This is shown in Fig. 25-18.

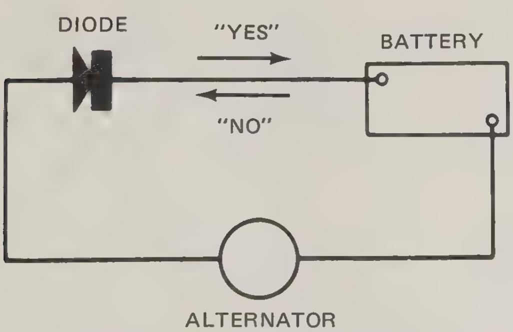


FIG. 25-17 Alternating current from an alternator can be rectified, or changed to direct current, by a diode for charging a battery. A diode is shown as a heavy arrow and rectangle in electrical diagrams.

The *thyristor* is a special sort of semiconductor device that is also called a silicon-controlled rectifier (SCR). It is shown in wiring diagrams as in Fig. 25-19. Current can flow between the cathode and anode in one direction but not in the other. This is the same way the diode acts. However, the thyristor differs from a diode in two ways:

1. Even though a voltage is applied across the thyristor, no current will flow until a signal is received at the gate, or door. This means that no current will flow until a small current flows in at the gate. This is the reason it is called a gate. When the small current flows in at the gate, the gate opens to let a large current pass between the cathode and anode.

2. Once started, the current will continue to flow between the cathode and anode even after the signal current to the gate stops. The current between the cathode and anode will continue to flow until the voltage on the cathode-to-anode is removed or reversed. This characteristic makes the thyristor perform an important job in the solid-state ignition system.

○ 25-9 ADVANTAGES OF SOLID-STATE IGNITION

Electronic ignition, also called breakerless ignition and solid-state ignition, does not use breaker points. The points are replaced by electronic components and circuits, as discussed in ○ 25-7.

There is a reason for getting rid of the breaker points. The primary current flows through the breaker points while they are closed. When the points open, the current tries to continue flowing. The result is an unwanted arc between the points. Ideally, the condenser would control the arc and prevent it from

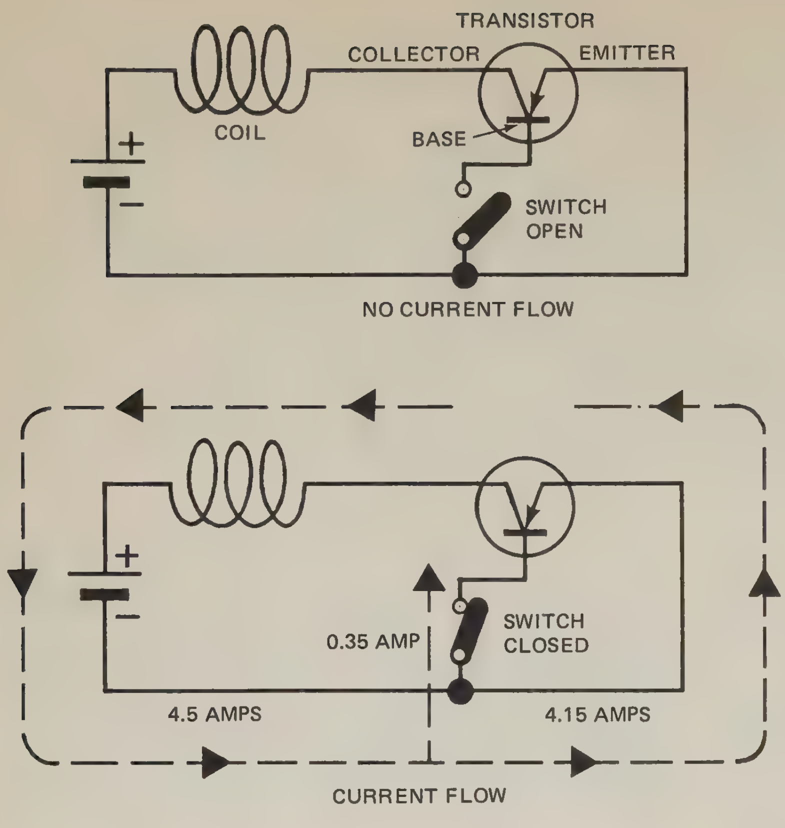


FIG. 25-18 (Top) When the switch is open, no current flows. (Bottom) When the switch is closed, current flows.

burning up the contact-point faces prematurely. But the condenser can never completely eliminate the arc. Therefore, the points do burn away in normal service. Engineers reasoned that if the points could be eliminated completely, much less ignition system maintenance would be required. New points would not have to be installed periodically. Only the spark plug would require periodic service.

Another important benefit of not having points is that ignition timing, once set, seldom if ever will need adjustment. In the breaker-point ignition system, timing must be checked and reset fairly often. This is because the wear on the rubbing block of the movable point causes the point gap to change. A change in point gap changes ignition timing. As the rubbing block wears, the point gap decreases. This increases dwell, which retards the ignition timing. A good rule to remember is that in normal service, as point gap decreases, the dwell increases and timing retards. Dwell is the number of degrees that the distributor cam rotates while the breaker points are closed.

Notice in the above discussion that capacitor-discharge ignition (CDI) was not included. CDI certainly is a type of solid-state or electronic ignition. But there is a difference in operation that puts it in a class by itself.

All the ignition systems we have discussed so far in this chapter are inductive ignition systems. They all operate by passing an electric current through the primary winding of the coil. Current flow through the winding causes a magnetic field to build up around the coil. That magnetic field is a method of energy storage. The primary energy that will later cause a spark to jump the spark-plug gap is stored in the magnetic field surrounding the coil. When it is the right time for a spark to fire the spark plug, the breaker points are opened. This stops the current flow through the primary winding. The magnetic field collapses almost instantly. This induces a high voltage in the secondary winding which, in turn, fires the

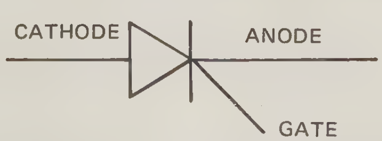


FIG. 25-19 The symbol for a thyristor used on wiring diagrams.

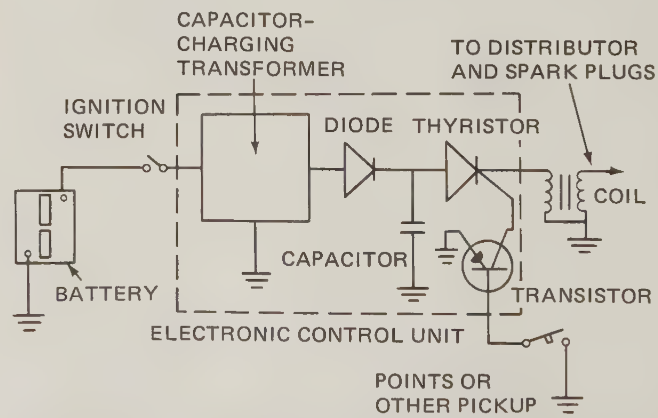


FIG. 25-20 A typical capacitor-discharge ignition (CDI) system for small engines. (*Champion Spark Plug Company*)

spark plug. This type of system is widely used on engines that have breaker points.

○ 25-10 CAPACITOR-DISCHARGE IGNITION SYSTEM Probably the most commonly used solid-state ignition system for small engines is CDI. Figure 25-20 shows in schematic view a typical CDI system for small engines. A capacitor plays an essential role in its operation. This is not the sort of capacitor discussed in ○ 25-4 and illustrated in Fig. 25-7. This is a much larger capacitor, because it must store more energy (electric charge, or electrons).

A capacitor-discharge ignition system stores its primary energy in a large capacitor, instead of storing the primary energy in a magnetic field around the coil. When a spark is needed at the spark plug, the capacitor is discharged. The primary energy stored in the capacitor becomes a surge of current that flows through the primary winding of the coil. As it does so, a magnetic field is induced in the secondary winding. As the magnetic field builds up, the voltage across the spark-plug gap increases rapidly, until the spark occurs.

The difference between the CDI system shown in Fig. 25-20 and the conventional induction-coil system is that the spark at the plug occurs when the circuit is closed. (Transistors are used in place of points in most CDI systems today.) The spark occurs on the buildup of the magnetic field in the secondary winding of the coil, and not on the collapse of the magnetic field. CDI is available for automobile engines and is standard equipment on some small engines, outboard engines, and motorcycles. Now, let us take a look at how a CDI system works.

Figure 25-21 is a schematic view of a CDI system for a one-cylinder engine. It includes the magnet on the

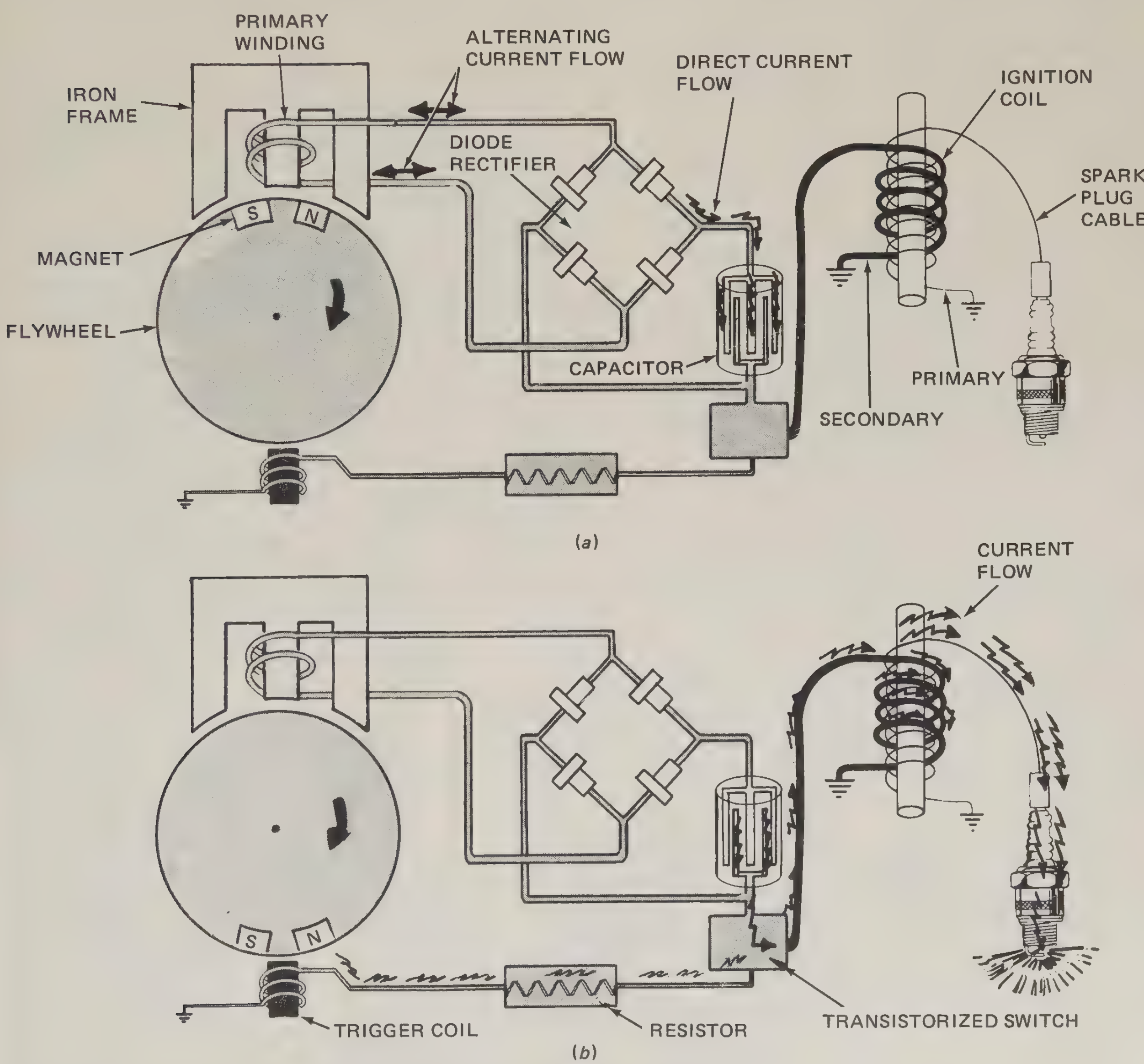


FIG. 25-21 Schematic view of a solid-state ignition system. The transistorized switch is essentially a switching device that, when triggered, allows a flow of current to pass through it or, when not triggered, prevents a flow of current.

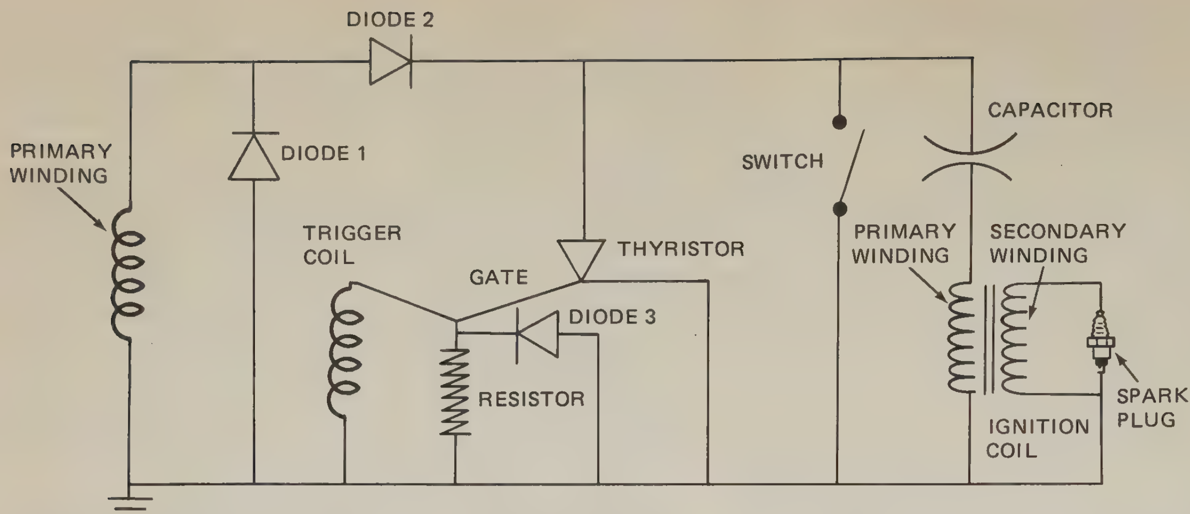


FIG. 25-22 Schematic drawing of a capacitor-discharge ignition (CDI) system used on small engines. (*Kohler Company*)

flywheel, as on the other type of magneto. However, there is only one winding (the primary winding) instead of two on the iron frame. The rest of the circuit is different, also. Figure 25-22 is the wiring diagram. Refer to Figs. 25-21 and 25-22 as we explain how the system works.

When the magnet moves past the primary winding, an alternating current is induced in the winding. This ac is changed to dc by the diodes so it can charge the capacitor. The electrical energy from the primary winding is then stored in the capacitor. As the flywheel continues its rotation, the magnet passes the trigger coil as shown in Fig. 25-21*b*. When this happens, a small current is induced in the coil. This current flows from the coil to the thyristor through the gate, as shown in Fig. 25-22. The thyristor is nonconducting until it is activated by a small signal current entering the gate. When the signal current from the trigger coil reaches the gate, the thyristor becomes conducting. Then the energy stored in the capacitor is released. It surges through the primary winding of the ignition coil. This quick burst of current produces a strong magnetic field. As the magnetic field builds up, it produces a high voltage in the secondary winding of the ignition coil. This high voltage then causes a high-voltage surge of current to flow from the secondary winding and across the spark-plug gap, producing an electric spark.

One essential difference between the actions of the primary and secondary windings in the standard magneto and their actions in the CDI system can be seen in Fig. 25-10. In the standard magneto, the high voltage in the secondary winding occurs when the magnetic field from the primary winding collapses. However, in the CDI system, the high voltage in the secondary winding occurs when the magnetic field from the primary winding builds up. The basic difference here is that the buildup occurs very rapidly, owing to the capacitor's sudden discharge through the thyristor. In the standard magneto (Fig. 25-10), the magnetic field from the primary winding builds up comparatively slowly.

○ 25-11 OTHER CDI SYSTEMS

Figure 25-23 shows a CDI system which includes an alternator. The alternator produces electric current to keep the battery charged. Charging systems are covered in Chap. 27. The primary winding that charges the capacitor is installed in the alternator stator. The alternator stator also includes windings which produce low-voltage ac. This low-voltage ac passes through the rectifier regulator, where it is changed to dc to charge the battery.

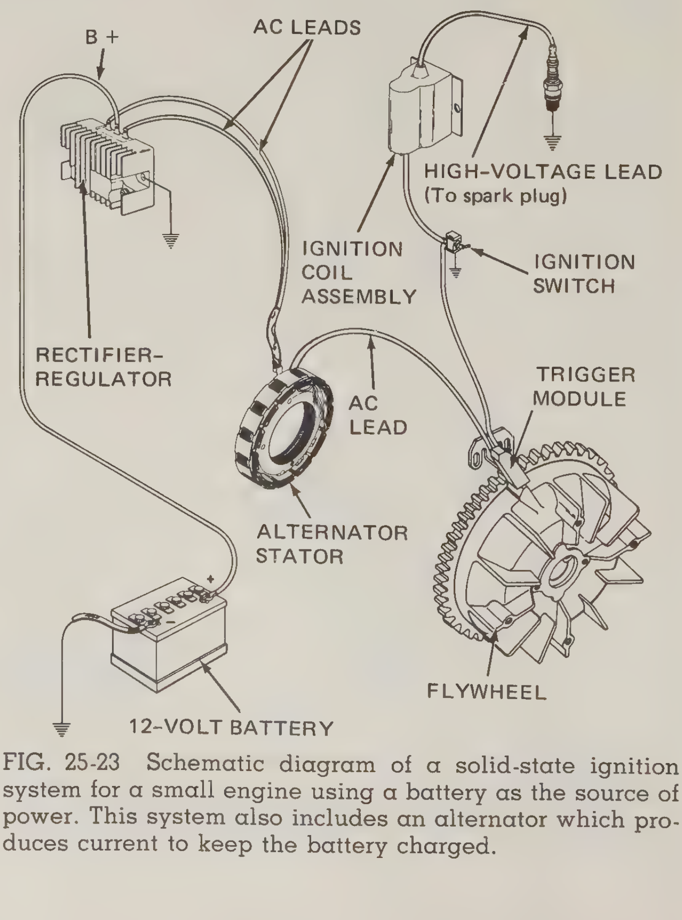


FIG. 25-23 Schematic diagram of a solid-state ignition system for a small engine using a battery as the source of power. This system also includes an alternator which produces current to keep the battery charged.

The ignition part of the system shown in Fig. 25-23 works the same way as the CDI system previously described and shown in Figs. 25-21 and 25-22. The magneto CDI system is used in engines of varying sizes, including those with six cylinders.

While all CDI systems operate on the same general principles, many different arrangements of the components are used. For further information on the operation of a specific CDI system on an engine that you must service, refer to the shop manual for the engine.

BATTERY IGNITION SYSTEMS

○ 25-12 PRINCIPLES OF BATTERY IGNITION SYSTEMS The battery ignition system differs in two basic respects from the magneto ignition system. First, in the battery ignition system, the current is supplied by a battery or alternator, just as in automotive ignition systems. Second, the ignition switch in the battery ignition system must be closed for the system to work. Figure 25-24 shows the wiring diagram of a small engine that uses a battery ignition system. Notice the absence of a flywheel magneto.

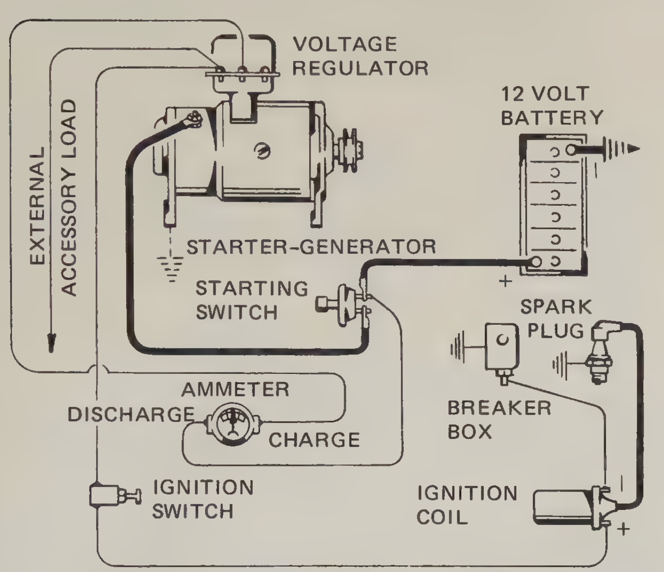


FIG. 25-24 Wiring diagram for an engine using a battery ignition system. (*Wisconsin Motor Corporation*)

The battery ignition system uses a separate ignition coil. It is wound similarly to the coil used in the magneto. However, in the automotive-type coil the primary winding is connected to the secondary winding. This connection is shown in Fig. 25-25. The two ignition systems are very similar except for the source of the primary current. Operation of the battery ignition system on a small engine is shown in Figs. 25-26 and 25-27. Rotation of a cam causes the contact points to close and open. When the contact points are closed, the primary winding of the ignition coil is connected to the battery. This allows current to flow through the primary winding and build up a strong magnetic field. Then, when the cam rotates so that the lobe on the cam opens the contact points, the current stops flowing in the primary winding. The magnetic field collapses, and this causes the secondary winding to produce a high-voltage surge. The high voltage causes a spark at the spark plug which ignites the compressed air-fuel mixture in the engine cylinder. Aiding in the quick collapse of the magnetic field is the condenser. It protects the contact points by providing a momentary place for the current to flow as the contact points begin to separate. Otherwise, the current would tend to continue to flow and would arc across the contact points, burning them. The con-

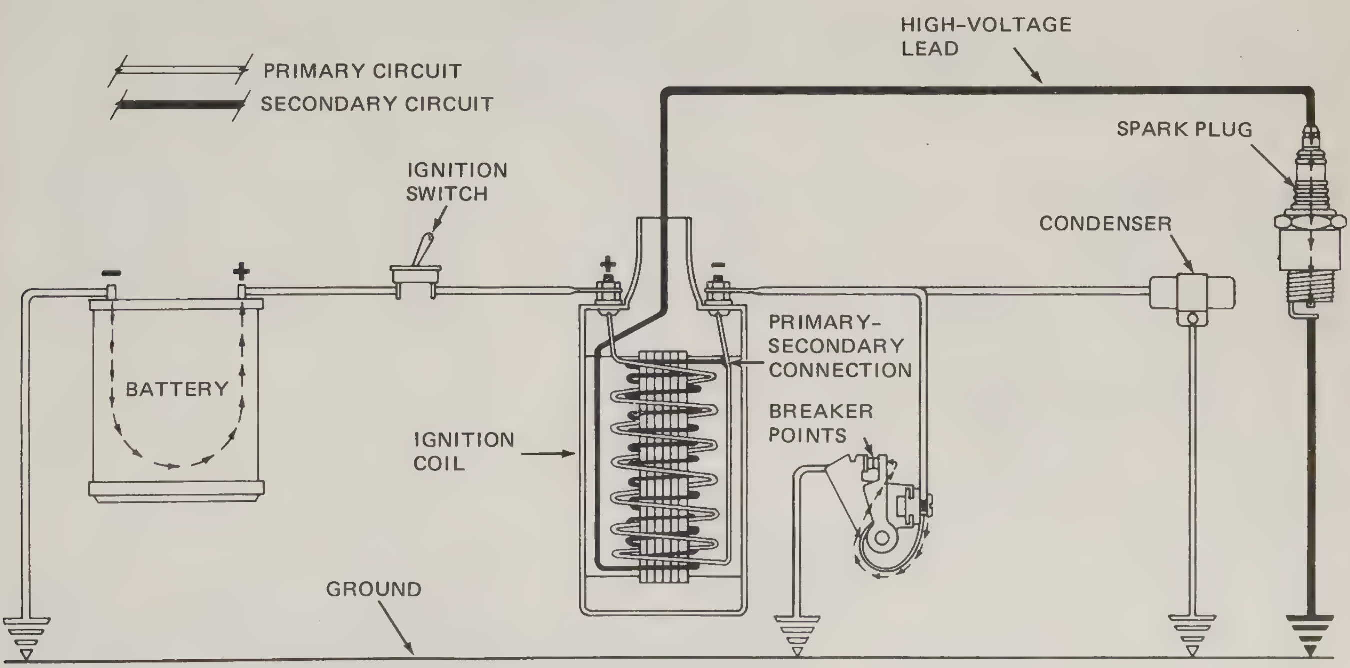


FIG. 25-25 Schematic drawing of a battery ignition system for small engines. (*Kohler Company*)

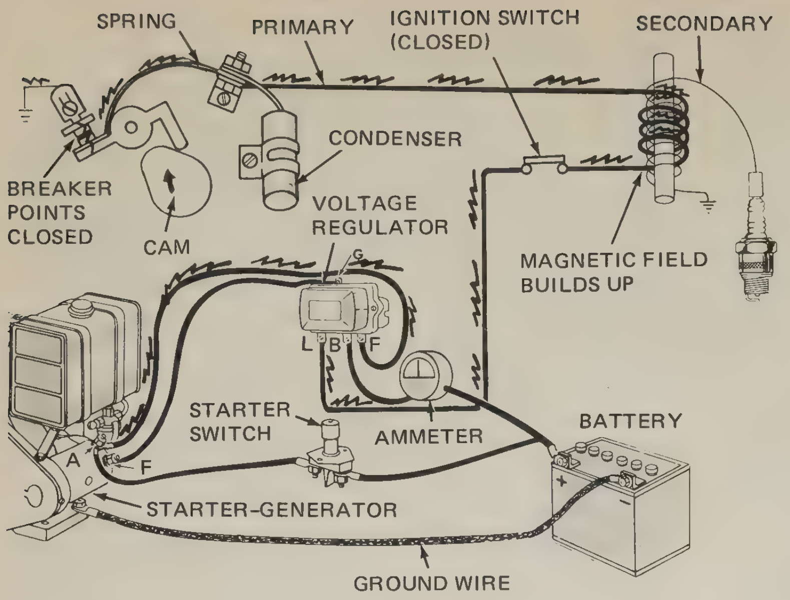


FIG. 25-26 Schematic view of a battery ignition system with the breaker points closed and current flowing from the battery through the primary winding of the ignition coil.

denser prevents arcing and, at the same time, brings the current flow to a quick stop. This hastens the collapse of the magnetic field in the ignition coil and thereby increases the high voltage in the secondary winding. The job of the condenser is the same as in the magneto ignition system.

○ 25-13 DISTRIBUTORS AND TIMERS Figure 25-28 shows the battery ignition system. The primary circuit consists of the battery, the contact points in the distributor, the primary winding in the ignition coil, the ignition switch, and the wiring. The secondary circuit includes the secondary winding in the ignition coil, the distributor cap and rotor, the spark plugs, and the connecting high-voltage cables.

When the contact points close, they connect the primary winding of the ignition coil to the battery. Current flows, and a magnetic field builds up around the coil. Then, when the contact points open, current stops flowing and the magnetic field collapses, thereby producing a high-voltage surge in the secondary winding of the ignition coil. This high-voltage surge passes through the center terminal of the distributor cap, the rotor, and cable, to the spark plug in the cylinder ready to fire.

The ignition distributor closes and opens the primary circuit at the proper time, and it distributes the resulting high-voltage surges from the ignition coil to the proper spark plugs. Figure 25-29 shows the top and sectional views of a typical distributor in a battery ignition system.

To sum up, the ignition distributor does two jobs. First, it closes and opens the circuit between the battery and the ignition coil. When the circuit closes, current flows in the ignition coil and builds up a magnetic field. When the circuit opens, the magnetic field in the coil collapses. The coil produces a high-voltage surge of current. The second job of the dis-

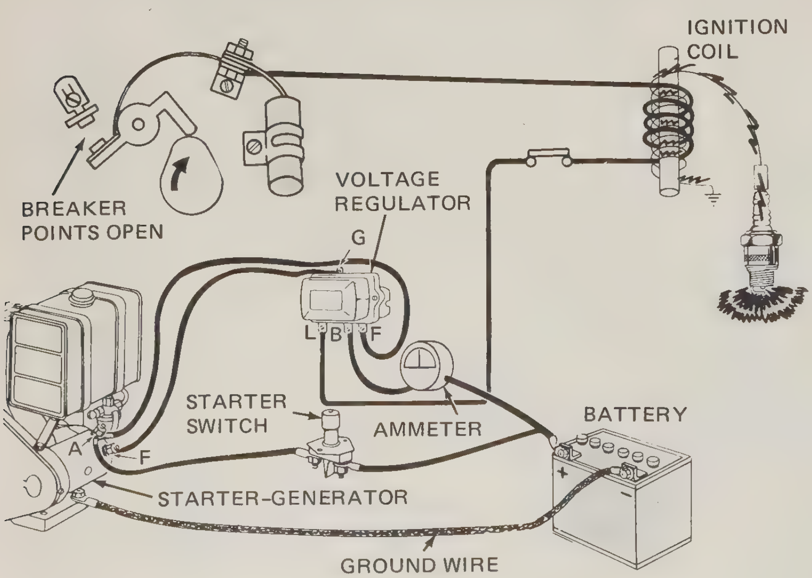


FIG. 25-27 Schematic view of a battery ignition system with the contact points open. The collapsing magnetic field in the ignition coil produces a high voltage in the coil secondary winding, and this causes a spark to occur at the spark plug.

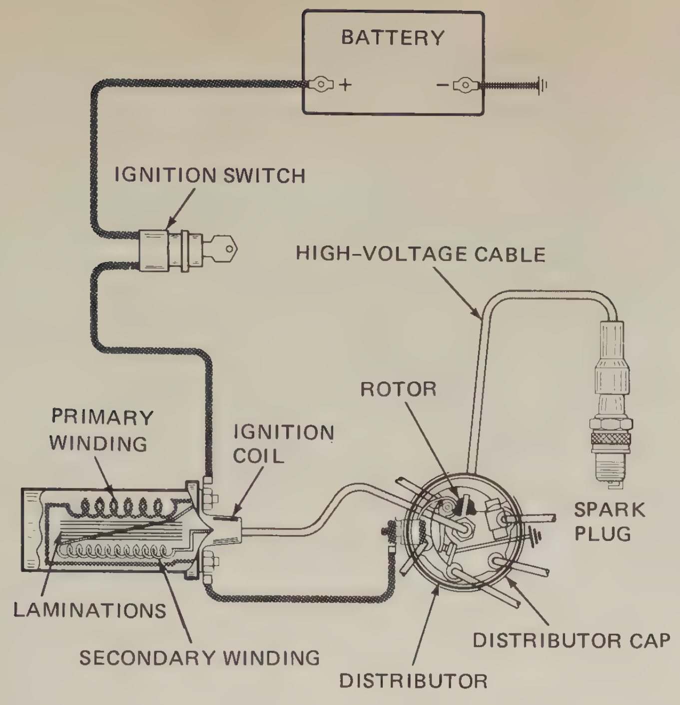


FIG. 25-28 Primary and secondary circuits in the battery ignition system.

tributor is to distribute that high-voltage surge to the correct spark plug at the correct time. It does this by means of the distributor rotor and cap and secondary wiring.

There are two basic types of distributors: (1) the type using contact points to close and open the coil primary circuit and (2) the type using a magnetic pickup and an electronic control unit to interrupt the current flow in the coil primary circuit. This second type is used in electronic ignition systems. In this chapter, we discuss the distributor with contact points.

This distributor (Figs. 25-29 and 25-30) consists of a housing, a drive shaft with breaker cam, an advance mechanism, a breaker plate with contact points, and a condenser, rotor, and cap. The shaft is driven by the engine through gears, and it usually rotates at one-half crankshaft speed. A typical mounting arrangement is shown in Fig. 25-31. Note that this illustration shows a timer instead of a distributor. When battery ignition is used on a one-cylinder engine, no voltage distribution is needed. The same spark plug fires every time the points open. Therefore, the device that controls the time of the spark is called a timer.

Rotation of the distributor or timer shaft and breaker cam causes the contact points to open and close. The

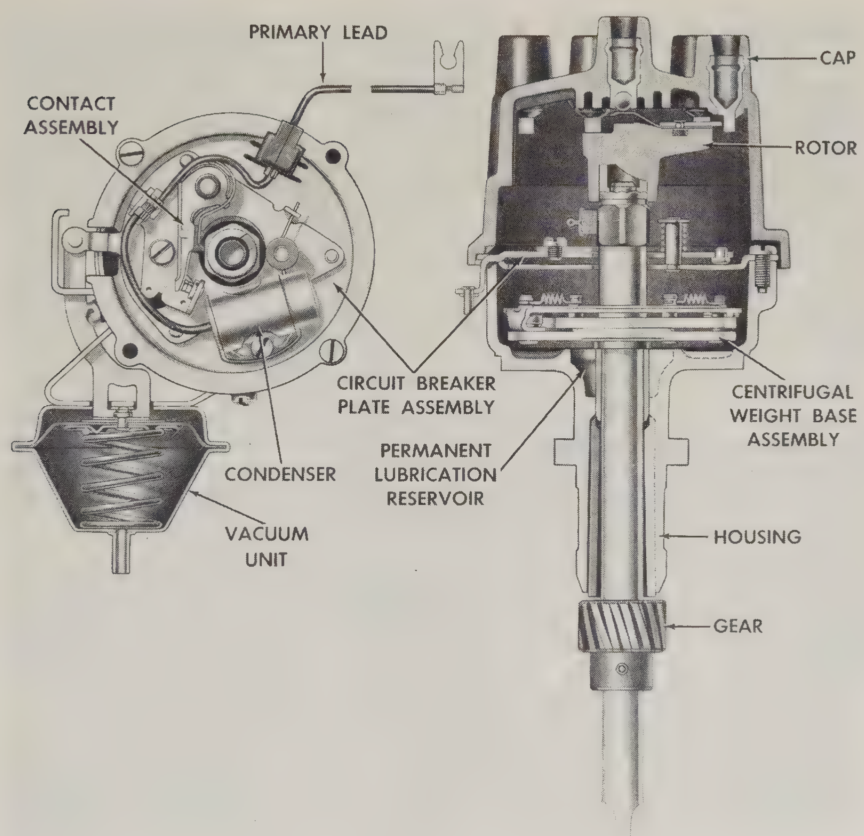


FIG. 25-29 Sectional and top views of an ignition distributor. In the top view, the cap and rotor have been removed so that the breaker plate can be seen. *(Delco-Remy Division of General Motors Corporation)*

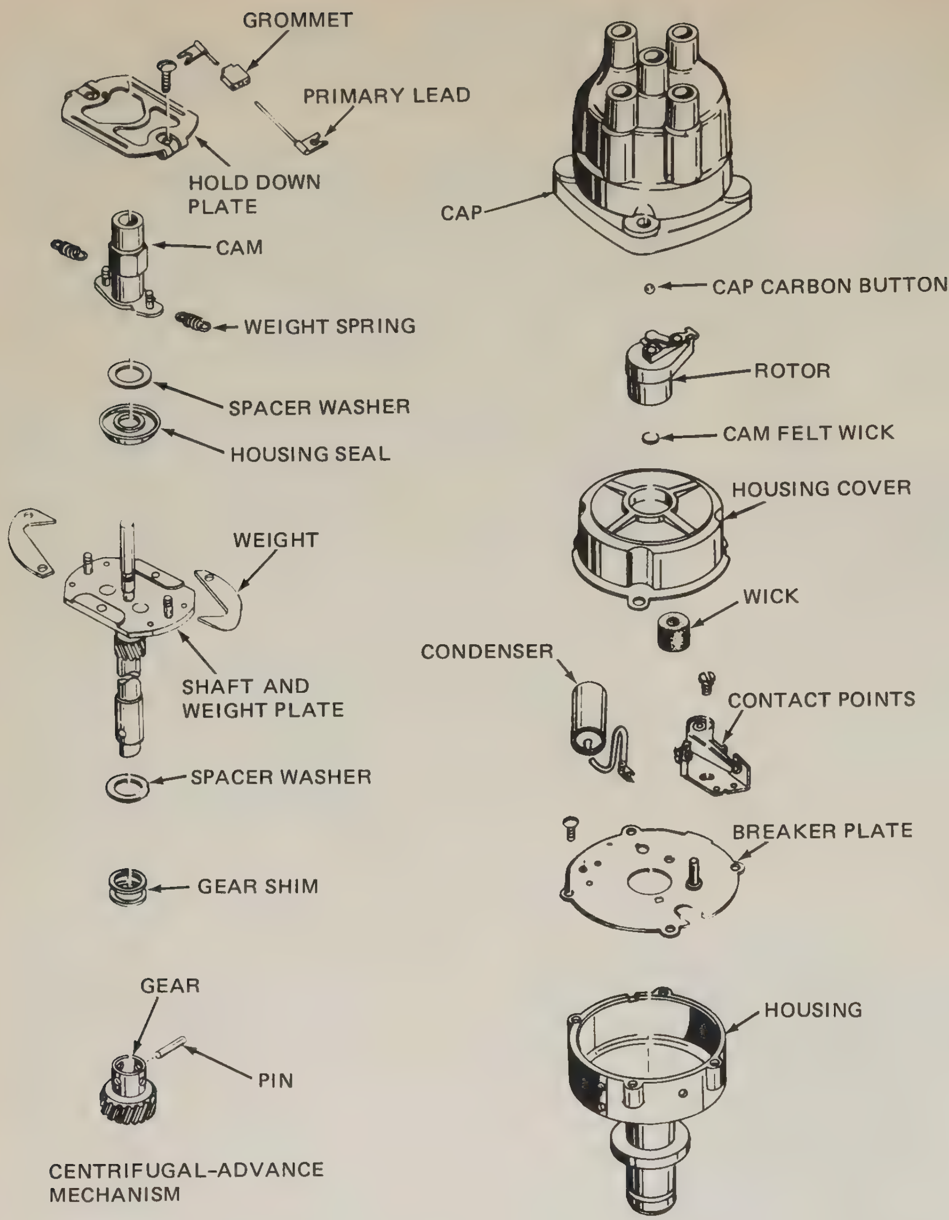


FIG. 25-30 Disassembled view of a small-engine distributor. (*Wisconsin Motor Corporation*)

breaker cam usually has the same number of lobes as there are cylinders in the engine. Notice the shape of the cam in the timer shown in Fig. 25-32. It has one flat spot to provide point closing on a one-cylinder engine. The spark occurs as the points open, approximately in the position shown in Fig. 25-32. The cam rotates at one-half of the crankshaft speed. The contact points close and open once with every breaker-cam rotation. Therefore, one high-voltage surge is produced by the ignition coil for every two crankshaft revolutions in a four-cycle engine.

The distributor rotor is not to be confused with the magneto rotor, which we discussed earlier. Figure 25-29 shows one type of distributor rotor. The rotor rotates with the breaker cam on which it is mounted. A metal spring and blade on the rotor connect the center terminal of the distributor cap with each outside terminal. As the rotor turns, the high-voltage surges from the coil are directed first to one spark plug, then to another, and so on, according to the firing order of the engine. Figure 25-33 shows this action of distributing the high voltage from the coil secondary winding to the spark plugs.

In some ignition systems, the breaker cam has only one-half as many lobes as engine cylinders. In these systems, there are two sets of contact points that are arranged to close and open alternately. This produces the same effect as the breaker cam and contact-point arrangement discussed previously.

○ 25-14 SPARK ADVANCE

Ignition timing refers to the adjustment of the distributor so that the breaker points open at just the right moment. When the breaker points open at the right moment, the high-voltage surge arrives at the spark plug at just the

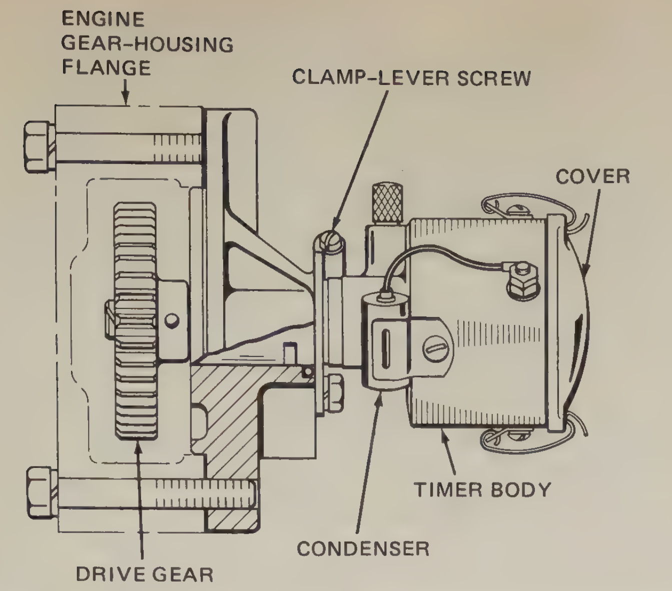


FIG. 25-31 Ignition timer used on a one-cylinder four-cycle engine that has battery ignition. (*Wisconsin Motor Corporation*)

right time. Ignition timing is adjusted by turning the distributor in its mounting, as we will discuss in Chap. 26. This adjustment shifts the position of the breaker points so that the cam lobe opens them at the proper moment.

When the engine is idling or running at slow speed, the high-voltage surge is timed to arrive at the spark plug before the piston reaches top dead center (TDC) on the compression stroke. When the engine speeds up, things happen much faster in the cylinders. The

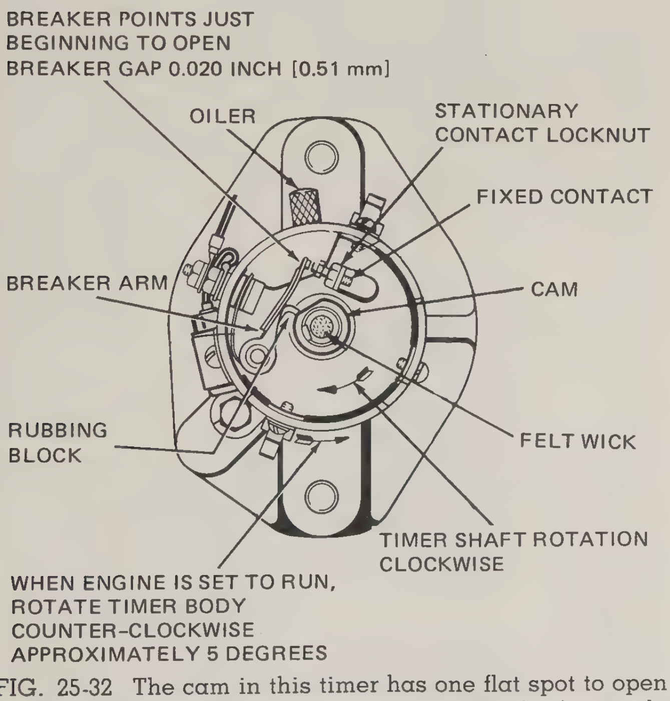


FIG. 25-32 The cam in this timer has one flat spot to open the points and provide ignition for a one-cylinder four-cycle engine. (*Wisconsin Motor Corporation*)

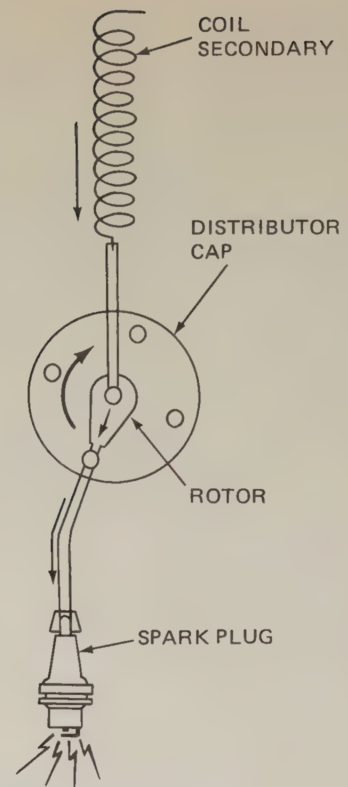


FIG. 25-33 Simplified illustration showing how the secondary winding of the coil is connected, through the rotor in the distributor, to the spark plug.

pistons move up on the compression strokes, go past TDC, and start down in far less time when the engine is running at high speed. However, the combustion process in the cylinder does not speed up the same amount.

Some engines have fixed timing. The spark is set to occur at the best time for the normal operating speed of the engine. With fixed timing, the engine is always timed at its maximum advance. This system is widely used with single-cylinder small engines which normally operate at a fixed speed. However, in engines operating at varying speeds, fixed timing is not satisfactory. Some way is needed to advance the timing according to the speed of the engine.

If the spark continued to appear at the spark plug at the same time at high speed as at low speed, this is what would happen: The spark would occur and combustion would start, but the piston would be past TDC and starting down again before the combustion pressure built up. The piston would move down so fast that it would get ahead of the pressure rise. This would mean a very weak push on the piston and a low engine power at high speed. Most of the power in the burning fuel would be wasted.

To prevent this, some distributors have centrifugal-advance mechanisms that advance, or push ahead, the spark as the engine speed increases. You can see the advance mechanisms assembled in Fig. 25-29. In Fig. 25-30, you can see the separate

parts of the advance mechanism. The parts include a pair of distributor advance weights. These weights are held by pivots on the base. The base is attached to the distributor shaft, and together they are called the main-shaft assembly or distributor-shaft assembly. Both weights have advance springs, which hold them in when the engine is idling. Figure 25-34 shows the two extreme positions of the advance weights. Figure 25-34 also shows the operation of the centrifugal advance and how it affects the time the spark occurs in the cylinders. At the top left, the engine cylinder is shown in sectional view. The engine is running at 1000 rpm. The spark is occurring at 8° before the piston reaches TDC on the compression stroke. This gives the compressed air-fuel mixture enough time to start burning and develop high pressure.

At the top right in Fig. 25-34, the positions of the two advance weights are shown. With the engine operating at 1000 rpm, there is no advance. With no advance, the spark occurs at the point of initial timing, in this case 8° before TDC.

As the engine speed increases, the advance weights push out. Their inner ends push against the advance cam, which is free to turn on the upper end of the distributor shaft. As the advance cam turns, it pushes the breaker cam forward in the direction of the rotation. Now the breaker-cam lobes move under

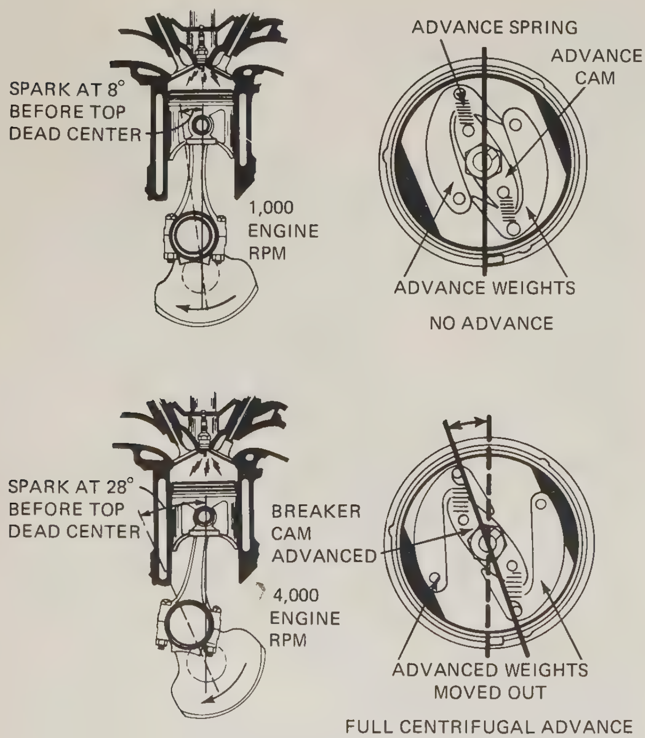


FIG. 25-34 Centrifugal-advance mechanism in the no-advance and full-advance positions. In the typical example shown, the ignition is timed at 8° before TDC on idle. There is no centrifugal advance at 1000 engine rpm, but there is a total advance of 28° (20° centrifugal advance plus 8° due to original timing) at 4000 engine rpm.

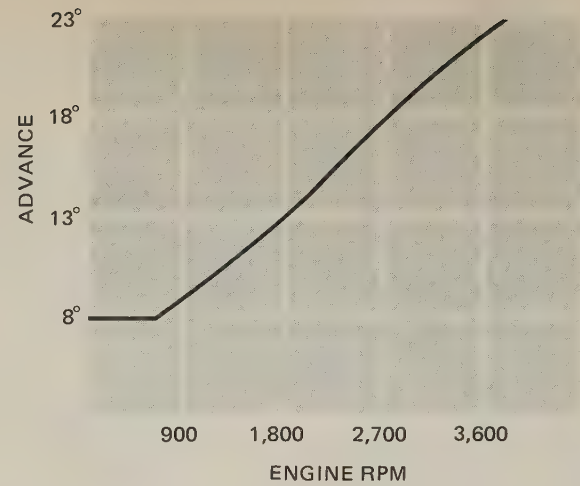


FIG. 25-35 A typical centrifugal-advance curve.

the breaker-cam rubbing block earlier. The points are opened earlier. As a result, the spark is advanced 20° for a total advance of 28° (8 + 20 = 28) before TDC when the engine is running at 4000 engine rpm (2000 distributor rpm). This arrangement gives the compressed mixture more time to burn and build up pressure on the piston. Therefore, the energy in the fuel is used more efficiently.

Distributors are designed to provide different advance curves for different engines. The spark is advanced by the centrifugal-advance mechanism just the right amount for every engine speed. Some engines need more advance than others, and the speeds at which the advances occur differ. For example, the curve in Fig. 25-35 is the centrifugal-advance curve for one engine. It shows that the ignition starts with an advance of 8° for any speed under 900 engine rpm (450 distributor rpm). As the speed increases, the advance begins. At 2700 engine rpm (1350 distributor rpm), the advance reaches 18° and is at a maximum of 23° at 3600 engine rpm (1800 distributor rpm).

Engineers design the shapes of the advance weights and the advance cam so that the proper advance for the engine is attained. In doing this, they take into consideration how the engine will be used and at what operating speed it will run. No two makes of engines are exactly alike. This is why the spark-advance curves are different for each engine.

○ 25-15 VACUUM ADVANCE

There is another condition under which some engines require additional spark advance. The condition occurs when the engine is operating at part throttle. At part throttle, less air-fuel mixture gets into the cylinders. There is less air-fuel mixture in the combustion chambers. With less fuel, the mixture takes longer to burn after it is ignited.

The problem is the same as before. If the mixture burns more slowly, the piston will be past TDC and moving down before the mixture has a chance to burn

and produce high pressure. As a result much of the energy in the fuel will be lost. The vacuum-advance mechanism is designed to prevent this loss.

You can see vacuum-advance mechanisms in Figs. 25-29 and 25-36. The mechanism contains a flexible diaphragm that is spring-loaded. The center of the diaphragm is connected by a linkage to the breaker plate, on which the breaker points are mounted. The breaker plate is supported on a bearing so that the plate can rotate a few degrees one way or the other. Now here is how the vacuum advance works:

The sealed side of the diaphragm is connected by a tube to the carburetor. On some engines, when the engine is idling, there is no vacuum advance. This is because the throttle is closed, and the throttle valve is below the vacuum passage in the carburetor air horn.

When the throttle is partly open, the vacuum in the intake manifold can work on the vacuum passage. The vacuum pulls the diaphragm in. This rotates the breaker plate a few degrees on its bearing. Therefore, the cam lobes move under the rubbing block of the movable point earlier. This opens the contact points earlier so that the spark is advanced.

With a wide-open throttle, there is very little vacuum in the intake manifold. Therefore, there will be no vacuum advance. Vacuum advance occurs when there is a vacuum in the intake manifold and less

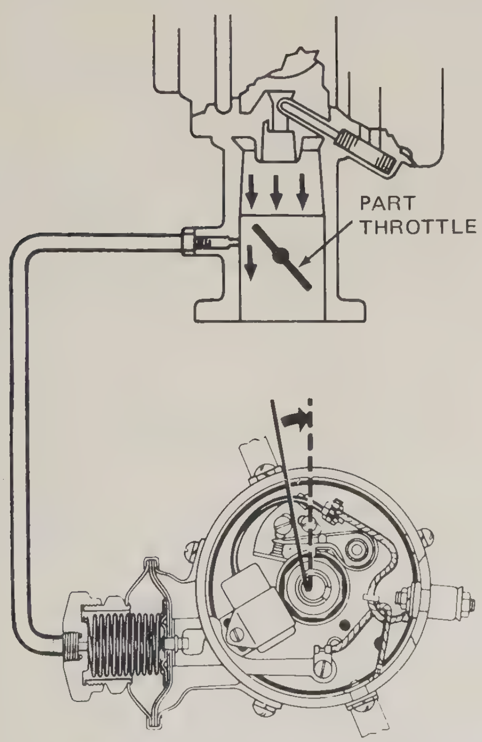


FIG. 25-36 Operation of the vacuum-advance mechanism. When the throttle valve swings past the opening, a vacuum is admitted to the vacuum-advance mechanism on the distributor. The breaker plate is rotated to advance the spark. (*Delco-Remy Division of General Motors Corporation*)

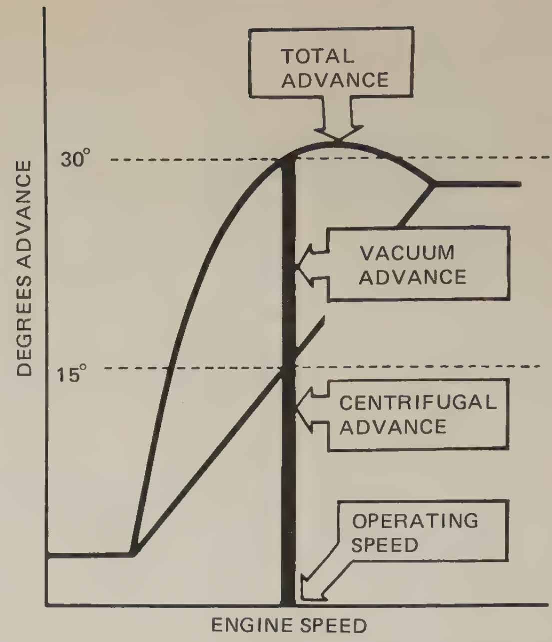


FIG. 25-37 Centrifugal- and vacuum-advance curves for one engine.

air-fuel mixture is getting into the cylinders. In other words, vacuum advance occurs only during part throttle.

In a distributor equipped with both centrifugal advance and vacuum advance, the two advances will combine to give the total advance needed for any operating condition. Centrifugal advance is based on engine speed. Vacuum advance is based on intake-manifold vacuum. Centrifugal advance always occurs as the engine speed increases. But vacuum advance is determined by the position of the throttle and the vacuum in the intake manifold.

A curve showing a typical combined advance is shown in Fig. 25-37. The vacuum advance is shown added to the centrifugal advance. In the example shown by a black line, the centrifugal advance is 15°. On top of this another 15° of vacuum advance is possible if the throttle is only partly open at the engine speed indicated. The result is a total of 30° possible advance.

○ 25-16 PIEZOELECTRIC IGNITION The piezoelectric ignition system does not use contact points, a battery, a condenser, or an ignition coil. Its operation depends on a peculiar property of some crystals. When these crystals are squeezed in a certain manner, they produce a voltage on opposing faces. Such crystals are used in many microphones and phonograph pickups. In the phonograph pickup, for example, the phonograph needle vibrates as it rides in the record groove. This vibration is applied to a crystal, and the crystal produces a varying voltage exactly matching the variations of pressure caused by the vibration. The voltage causes current to flow through an amplifier and speaker so that sound is produced.

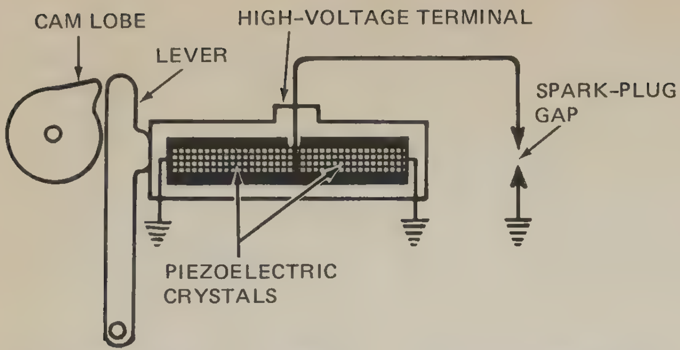


FIG. 25-38 Simplified schematic drawing of a piezoelectric ignition system for a one-cylinder engine.

The piezoelectric principle has been applied to some single-cylinder engines used on lawn mowers. There is a possibility that this principle will be developed for use in multiple-cylinder engines. The system for the single-cylinder engine is illustrated in Fig. 25-38. The cam is driven by the engine and has a single lobe. At the proper time, the cam lobe comes up under the lever, causing the lever to apply pressure to the two piezoelectric crystals contained in an insulating tube. The outer ends of the crystals are grounded. The inner ends are connected to the high-voltage terminal. This terminal is connected to the spark plug. The pressure on the crystals causes them to produce a very high voltage of up to 20,000 volts or more. This high voltage causes a spark at the spark plug.

A piezoelectric crystal can continue to supply high-voltage surges in this manner almost indefinitely. A simple way of thinking about the process is to consider that a crystal is composed of atoms, which are formed into molecules. The atoms are made up partly of electrons and protons.

These particles, which are negatively and positively charged, are in an orderly arrangement in the crystal. When pressure is applied, this orderly arrangement is disturbed. The molecules and atoms are pushed out of position. In effect, all are turned in such a way that their negative sides point one way and their positive sides point the other. Then they act somewhat like battery cells connected in series. High voltages appear on the opposing faces of the crystal. If these opposing faces are connected by an electric circuit, current will flow through the circuit.

REVIEW QUESTIONS

1. What is the purpose of the ignition system?
2. What is a magneto?
3. Describe a flywheel magneto.
4. In a flywheel-magneto ignition system that uses contact points, does the spark occur at the spark plug as the points open or as the points close?
5. How do you stop an engine that has a flywheel magneto?
6. What is the difference between a flywheel magneto and an external magneto?
7. What is an impulse coupling?
8. Why do some engines use more than one set of breaker points?
9. What is a breakerless ignition system?
10. Explain the actions of a diode.
11. Explain the actions of a transistor.
12. Explain the actions of a thyristor.
13. How does wear of the breaker points affect ignition timing?
14. What is a capacitor-discharge ignition system?
15. Does the electronic ignition system use contact points?
16. What are the two circuits through the contact-point type of ignition distributor?
17. Explain how the starting and stopping of a flow of current in the ignition-coil primary winding produces a high-voltage surge in the secondary winding?
18. Name the essential parts in the primary circuit.
19. Name the essential parts in the secondary circuit.
20. Describe the cap and rotor action.
21. Explain the condenser effect.
22. What are the two general types of spark-advance mechanisms?
23. Describe the operation of the centrifugal-advance mechanism.
24. Describe the operation of the vacuum-advance mechanism.
25. What is piezoelectric ignition?

SELF PROJECTS

1. Refer to the line drawings in the chapter showing the primary and secondary circuits. Draw your own versions of these circuits. Use different colors for the different circuits and for the system components. For example, you could use blue for the secondary circuit, red for the primary, and black for the components. File your drawings in your notebook.
2. If you can find a discarded ignition coil and condenser, take them apart. Use a hacksaw to cut the top off the cans.

26
Chapter

Ignition-System Service

After studying this chapter, you should be able to:

1. **Demonstrate how to service a flywheel-magneto ignition system**
2. **Demonstrate how to replace and adjust breaker points**
3. **Demonstrate how to time the ignition**
4. **Describe how to check and service spark plugs**
5. **Explain how to check the impulse coupling on an external magneto**
6. **Demonstrate how to troubleshoot the battery ignition system**
7. **List the three categories of ignition-system failures**
8. **Demonstrate how to make the spark test**
9. **List the causes of pitted breaker points**

○ 26-1 FLYWHEEL-MAGNETO IGNITION-SYSTEM SERVICE Without a good spark delivered to the spark plug at the correct time, the engine will perform poorly or not at all. Producing a good spark and delivering it to the spark plug at the correct time depend on several factors. The contact points must be in good condition and properly adjusted. The magneto stator coils or ignition coil, condenser, wiring (particularly the high-voltage lead to the spark plug), and connections must be in good condition. The spark plug also must be clean and properly gapped. Now let us see how to check these various components of the small-engine magneto-ignition system. In Chap. 29, on troubleshooting small engines, we describe how to diagnose troubles such as failure to start, lack of power, engine surging, loss of power as the engine runs, and irregular firing.

○ 26-2 CHECKING THE SPARK One of the checks to be made is the spark test. To make it, disconnect the high-voltage lead from the spark plug. Pull back the rubber boot on the spark plug to expose the metal clip, or put a bolt into the boot to get a metal contact. Hold the metal clip or bolt about $^{3}/_{16}$ inch [5 mm] from the cylinder head and crank the engine, as shown in Fig. 26-1. If strong sparks jump to the cylinder head, the ignition system is probably working properly. If no spark occurs, then the ignition system is probably at fault and it should be checked. Some causes of trouble could be dirty or worn contact points, points out of adjustment, a defective capacitor (condenser), a defective high-voltage lead that lets voltage leak off to ground, a defective ON-OFF switch, and a defective magneto coil.

If a spark does jump from the bolt or clip to the cylinder head, examine the spark plug to see if it can deliver the spark to the engine. Remove the plug and reattach the high-voltage lead to it. Lay or hold the plug against the cylinder head as shown in Fig. 26-2, and crank the engine. Watch for a spark at the plug

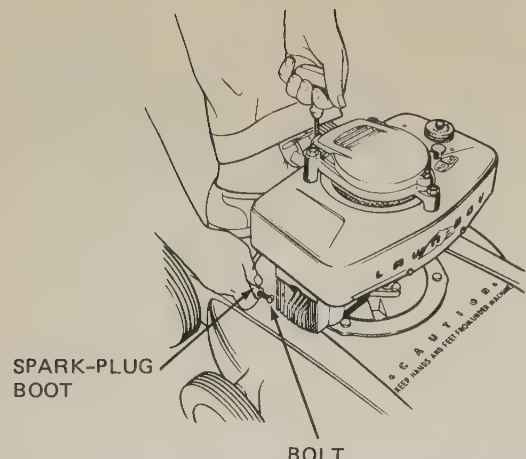


FIG. 26-1 Check the ignition system by disconnecting the high-voltage lead from the spark plug and putting a bolt into it to get metal contact. Hold the lead with the bolt in it about $^3/_{16}$ inch [5 mm] from the cylinder head while cranking the engine. (*Lawn Boy Division of Outboard Marine Corporation*)

gap. If no spark jumps, the spark plug is probably at fault. Examine it for cracks, black sooty deposits on the porcelain or electrodes, burned electrodes, or a wide gap (Fig. 26-3). Any of these could prevent a good spark. Spark-plug service is covered in detail in ○ 26-7.

A refinement of this test uses a special spark tester. To use the tester, remove the spark plug lead and connect it to the tester, as shown in Fig. 26-4. Ground the electrode of the tester that gives 0.166-inch [4.22-mm] gap, and crank the engine. If a good spark jumps the gap, the ignition system is working properly.

If the engine runs but misses, check the ignition system by inserting the tester between the spark-plug lead and the spark plug. Run the engine and carefully watch the spark at the tester gap. If the spark is not regular and steady, there is trouble in the ignition system. The points, wiring, and coil should be checked.

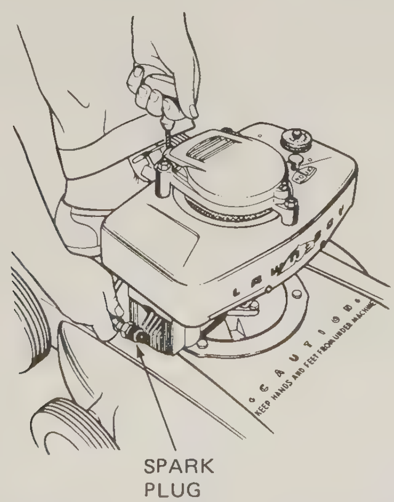


FIG. 26-2 Checking the plug for a spark. Hold the plug by the rubber boot. Do not hold the plug. (*Lawn Boy Division of Outboard Marine Corporation*)

If you do not get a spark on the spark test, then check for the following:

1. Bad insulation or poor connections in the wiring
2. A grounded ignition switch which prevents the opening of the primary circuit so that primary current is not interrupted when the contact points open
3. A shorted condenser, which would have the same effect as a grounded ignition switch
4. A magneto coil that is shorted, open, or grounded so it cannot produce high voltage
5. A loss of magnetism in permanent magnets on the flywheel or in the external magneto rotor
6. Contact points that are dirty, worn, or out of adjustment

If the engine backfires or kicks back when starting, the breaker-point gap may be too wide, causing ignition to occur too early in the compression stroke. When this happens, the resulting increase in pressure forces the piston back down before it can reach TDC. An early spark will also cause detonation when the engine is running. The remedy is to reset the timing. On some magnetos, the only adjustment is to change the breaker-point opening. On others, you can also move the breaker plate to change the timing.

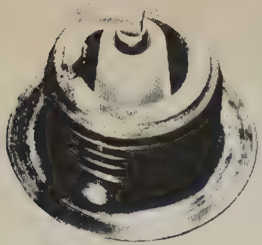
○ 26-3 CHECKING INTERNAL-MAGNETO POINTS

On many engines, to check the breaker points in a flywheel magneto, you must remove the flywheel. On other engines, the breaker points are mounted in an external breaker box, as discussed later.

CAUTION: To prevent accidental starting, always disconnect the spark-plug wire from the spark plug when working on the engine.

First, if the engine has a rope-rewind or a windup starter, remove the starter assembly. On some engines with an electric starter-generator, the flywheel will have a stub shaft on which the drive pulley mounts. This stub shaft must be removed. Then the flywheel shroud must be removed so you can get at the flywheel.

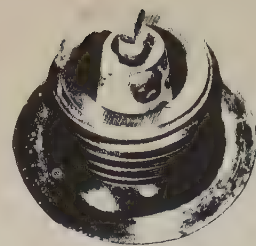
Next, remove the flywheel attaching nut. Some of these nuts have right-hand threads, and some have left-hand threads. You can usually determine which is which by considering the normal rotation of the engine. If the flywheel turns clockwise while you are cranking it, then the nut has a right-hand thread. Cranking the engine tends to tighten the nut. If the nut has a left-hand thread, then turning the flywheel will tend to loosen the nut.



NORMAL

Brown to grayish tan color and slight electrode wear. Correct heat range for engine and operating conditions.

RECOMMENDATION: Properly service and reinstall.



SPLASHED DEPOSITS

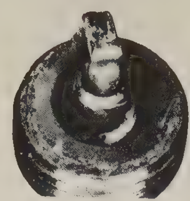
Spotted deposits. Occurs shortly after long-delayed tune-up. After a long period of misfiring, deposits may be loosened when normal combustion temperatures are restored by tune-up. During a high-speed run, these materials shed off the piston and head and are thrown against the hot insulator.

RECOMMENDATION: Clean and service the plugs properly and reinstall.

CARBON DEPOSITS

Dry soot.

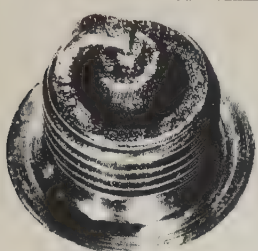
RECOMMENDATION: Dry deposits indicate rich mixture or weak ignition. Check for clogged air cleaner, high float level, sticky choke,or worn breaker contacts. Hotter plugs will temporarily provide additional fouling protection.



HIGH-SPEED GLAZING

Insulator has yellowish, varnish-like color. Indicates combustion chamber temperatures have risen suddenly during hard, fast acceleration. Normal deposits do not get a chance to blow off, instead they melt to form a conductive coating.

RECOMMENDATION: If condition recurs, use plug type one step colder.



OIL DEPOSITS

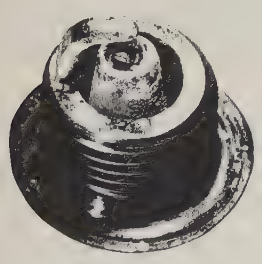
Oily coating.

RECOMMENDATION: Caused by poor oil control. Oil is leaking past worn valve guides or piston rings into the combustion chamber. Hotter spark plug may temporarily relieve problem, but positive cure is to correct the condition with necessary repairs.

MODIFIER DEPOSITS

Powdery white or yellow deposits that build up on shell, insulator, and electrodes. This is a normal appearance with certain branded fuels. These materials are used to modify the chemical nature of the deposits to lessen misfire tendencies.

RECOMMENDATION: Plugs can be cleaned or, if replaced, use same heat range.



TOO HOT

Blistered, white insulator, eroded electrodes and absence of deposits.

RECOMMENDATION: Check for correct plug heat range, overadvanced ignition timing, cooling system level and/or stoppages, lean air-fuel mixtures, leaking intake manifold, sticking valves, and if car is driven at high speeds most of the time.

PREIGNITION

Melted electrodes. Center electrode generally melts first and ground electrode follows. Normally, insulators are white, but may be dirty due to misfiring or flying debris in combustion chamber

RECOMMENDATION: Check for correct plug heat range, overadvanced ignition timing, lean fuel mixtures, clogged cooling system, leaking intake manifold, and lack of lubrication.

FIG. 26-3 Appearance of spark plugs related to causes of spark-plug conditions. (*Champion Spark Plug Company*)

You will need a wrench to fit the nut and some means of holding the flywheel. Figure 26-5 shows one holder in use while the nut is being loosened. Other types of holders are available. You also can use a wooden block, as shown in Fig. 26-6. The engine must be solidly mounted when a wood block is used. On some engines, it is possible to loosen the flywheel nut by tapping the wrench sharply with a soft hammer (plastic, lead, or brass-headed).

Next, remove the flywheel from the crankshaft. There are several ways of doing this. If the shaft is tapered, you can install a nut on the threads, turning it down so that the threads on the end of the shaft are almost exposed. Then rap the nut with a soft hammer, as shown in Fig. 26-7. The nut takes the blow and protects the threads on the shaft. Some manufacturers supply a special puller which serves the same purpose as the nut but provides better protection for the threads. Figure 26-8 shows this puller in use. It is turned down on the threads until it is about $^1/_{16}$ inch [1.6 mm] from the flywheel. Then the puller is given a

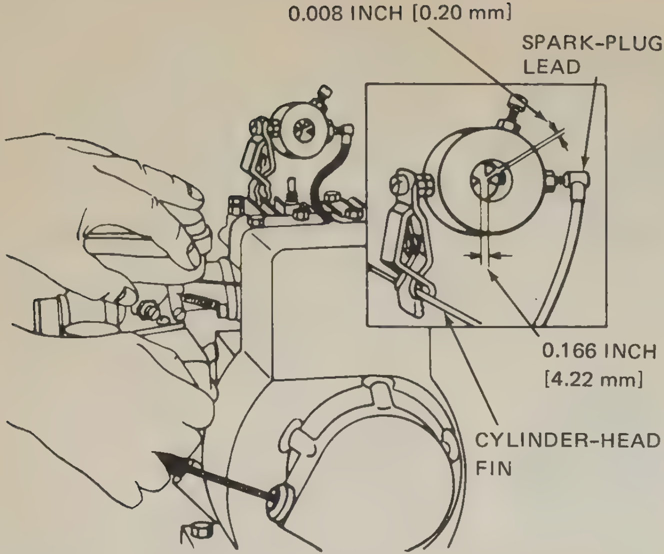


FIG. 26-4 Checking the spark with a special spark-gap tester. (*Briggs & Stratton Corporation*)

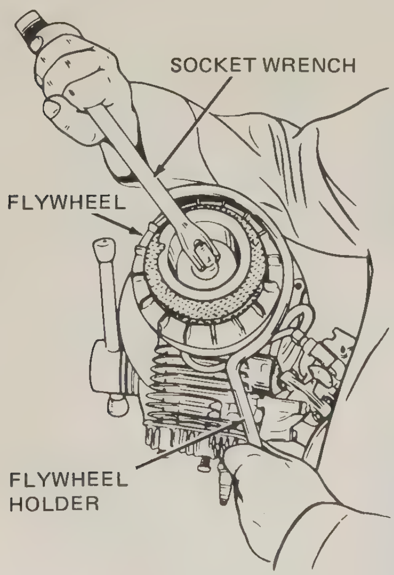


FIG. 26-5 Removing the flywheel attaching nut while holding the flywheel with a special holder. (*Tecumseh Products Company*)

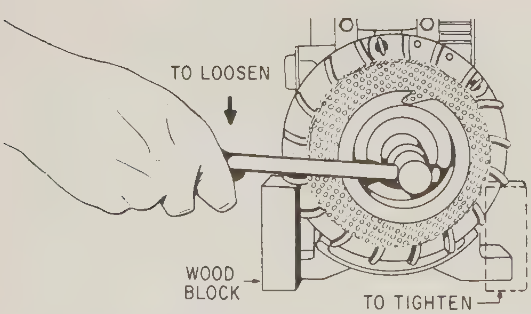


FIG. 26-6 The nuts on larger flywheels can be loosened by holding the flywheel with a block of wood, as shown. (*Briggs & Stratton Corporation*)

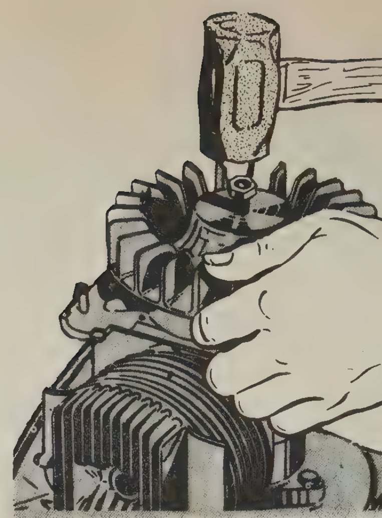


FIG. 26-7 One way to loosen the flywheel from a tapered shaft.

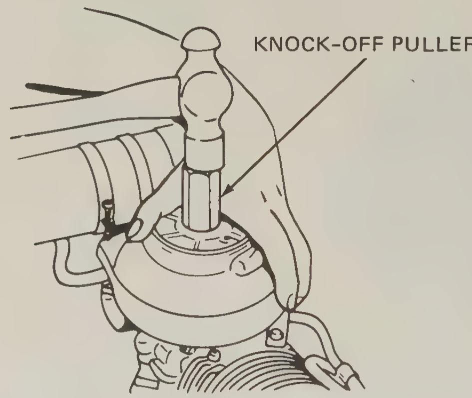


FIG. 26-8 Using a special flywheel knockout puller to loosen the flywheel from the shaft. (*Tecumseh Products Company*)

sharp rap with a soft hammer. One or two raps with the hammer on the nut or puller should loosen the flywheel. However, too much hammering can weaken the permanent magnets and also might damage the crankshaft bearings.

If the shaft is not tapered, then you will need to use a different sort of flywheel puller. A pressure-screw puller has threads which gradually pull the flywheel off the shaft (Fig. 26-9). Attach the puller with screws. Then turn the handle. The pressure screw rests on the end of the shaft. As the screw is turned down in the puller, the flywheel is pulled loose from the shaft. There are other kinds of pullers. Figure 26-10 shows another type that uses self-tapping screws.

When removing the flywheel, do not drop it or handle it roughly. You can knock most of the magnetism out of the permanent magnets with rough treatment. Heat from a welder or cutting torch also can take the magnetism out of magnets.

On some engines with internal points, the points are protected by a breaker-point dust cover, as shown

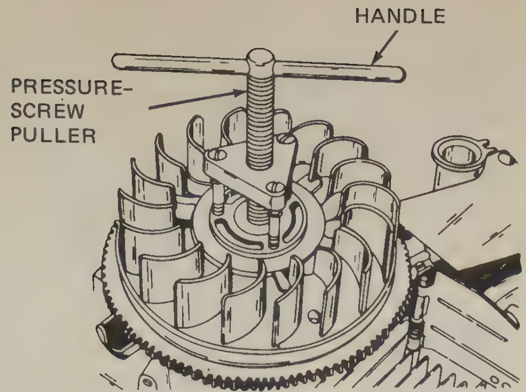


FIG. 26-9 Using a screw-thread puller to remove the flywheel from the shaft. (*Tecumseh Products Company*)

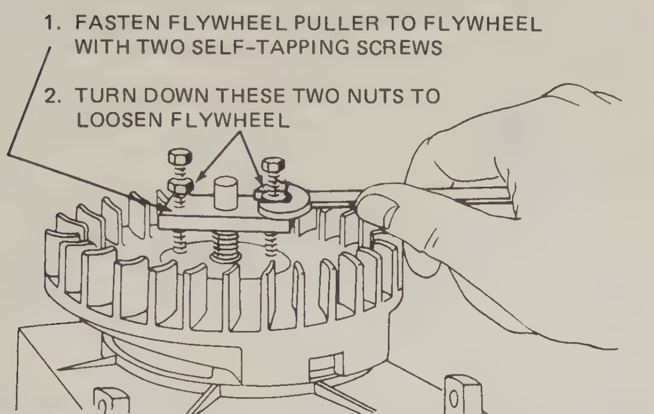


FIG. 26-10 Using self-tapping screws to remove the flywheel from the crankshaft. (*Briggs & Stratton Corporation*)

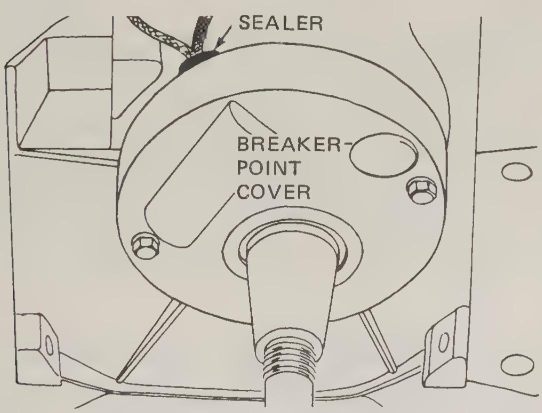


FIG. 26-11 The breaker-point cover, also called the dust cover. (*Briggs & Stratton Corporation*)

in Fig. 26-11. Remove this cover carefully. If it is bent during removal, it will not seal on reassembly and a new cover will be required. Note that the place where the leads come out from under the cover is sealed. This seal is made with nonhardening Permatex or a similar sealer when the cover is replaced. A poor seal around the rim of the cover or at the leads will allow dirt to get on the contact points. The points will burn and require early replacement.

○ 26-4 BREAKER-POINT SERVICE

The breaker points have a stationary point and a movable point on a contact arm. The design and arrangement of the points vary with different engines. On some engines, the stationary point is on the end of the condenser. On others, it is mounted on a bracket. The breaker arm, on which the movable point is mounted, is pivoted so that it can move the point up against or away from the stationary point. There are various arrangements to move the contact arm. Figures 26-12 to 26-14 show three arrangements. Regardless of the method, when the high point, or lobe, of the cam comes

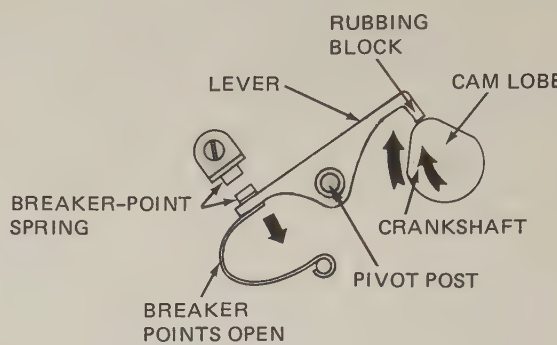


FIG. 26-12 Arrangement with breaker points being opened by a cam working directly on the breaker lever.

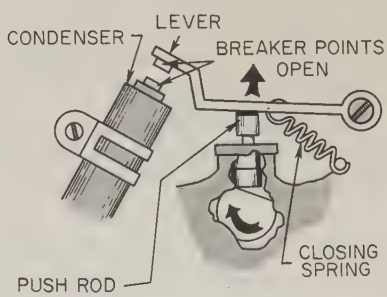


FIG. 26-13 With this arrangement, the cam works a push rod which actuates the lever to open the points.

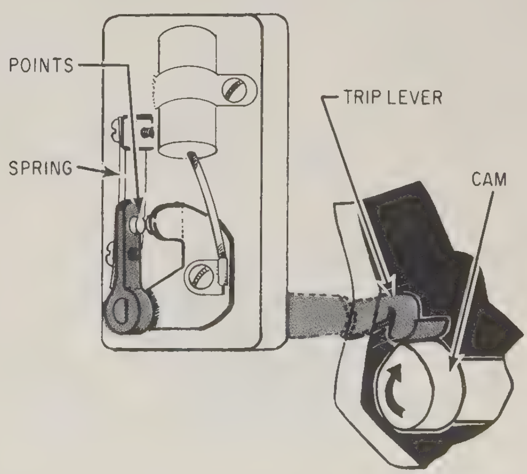


FIG. 26-14 With this arrangement, the cam operates a trip lever which actuates the lever on which one contact is mounted.

around under the rubbing block (as shown in Fig. 26-12), the push rod or plunger (shown in Fig. 26-13), or the trip lever (shown in Fig. 26-14), the contact arm is moved and the contact points separate. The cam is on the crankshaft on two-cycle engines. On some four-cycle engines, the cam is on the camshaft.

Cleaning Points Once the contact points are exposed by removal of the flywheel and the dust cover (where present), examine them for oxidation or pits. If they are only slightly burned or pitted, they can be cleaned with an ignition file, as shown in Fig. 26-15. It is not necessary to file the points until they are smooth. Just remove the worst of the high spots. Blow out all dust after cleaning the contacts. Pull a strip of clean bond paper between the points (with points closed) to remove the last traces of filings.

Never use emery cloth or sandpaper to clean the points. Particles of emery or sand will embed in the points and cause erratic operation and possible point burning.

Installing New Points If the points are badly burned, worn, or pitted, they should be replaced. Severe burning of the points could be due to a defective condenser, improper adjustment, or oil on the contact surfaces. Check for these conditions before replacing the points. Various methods of attaching the stationary point and breaker arm are used. On one type, the point assembly is removed by removing the condenser wire from the breaker-point clip and then loosening the adjusting lock screw so the assembly can be slipped off. On the type shown in Fig. 26-16, the breaker arm is removed by loosening the screw holding the post in position. The stationary contact is on the condenser and is removed along with the condenser by loosening the condenser-clamp screw.

On engines which use a push rod or plunger to operate the breaker arm, the engine manufacturer recommends a check of the plunger and plunger hole whenever the contact points are removed. A plug gauge is used to check the hole for wear. If the hole is enlarged, it will allow oil to enter the breaker-point compartment where it will get on the points and cause them to burn. If the hole is worn, it must be reamed out and a special bushing installed. The

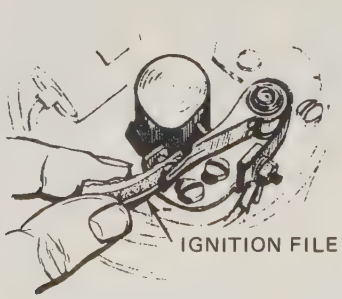


FIG. 26-15 The breaker points can be cleaned with a contact file.

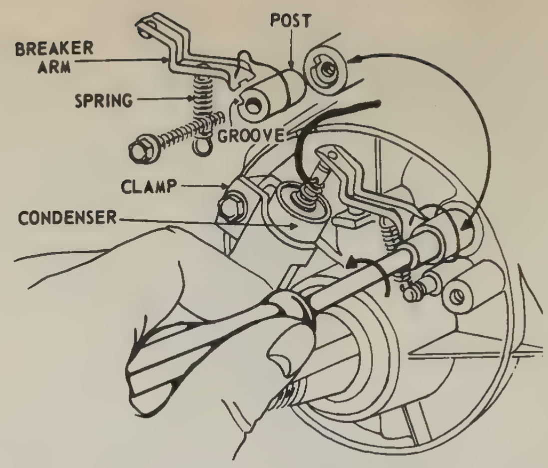


FIG. 26-16 On this design, the breaker-point assembly is removed by loosening the screw holding the post. The condenser, with stationary point, is removed separately by loosening the condenser-clamp screw. (*Briggs & Stratton Corporation*)

plunger should be checked for wear. If the plunger is worn and too short, replace it with a new plunger. Be sure the plunger is installed correctly.

On the type of breaker arm that uses a rubbing block, as shown in Fig. 26-12, check for rubbing-block wear. As the rubbing block wears, it changes the breaker-point opening and also can change the timing.

Examine the breaker cam for wear. Some cams on two-cycle engines are integral with the crankshaft. If they are badly worn, the crankshaft must be replaced. On other engines, the cam is a separate collar locked to the crankshaft by a key. On these, the cam can be replaced if it is worn.

Check for a leaky crankshaft seal. A leaky seal will allow oil to get on the breaker points so that they would burn rapidly. It should be replaced.

After removing the old points, install the new points, carefully noting the proper relationship, as shown in Figs. 26-12 to 26-16. Then check the point opening and adjust it as necessary. Finally, check the ignition timing.

Adjusting Points To adjust the breaker points, first make sure that they are properly aligned. Figure 26-17 shows the right and wrong ways to align points. Usually, the points are properly aligned and no adjustment is required. However, if new points are misaligned, adjust them by slightly bending the bracket supporting the stationary point.

The point opening is a critical adjustment. If it is excessive, ignition timing can be too advanced. This can cause engine backfiring on starting, as well as detonation when the engine is running.

To adjust the point opening, turn the crankshaft in the direction of normal rotation until the cam opens the points to the widest position. Then use a feeler gauge of the proper thickness to measure the gap

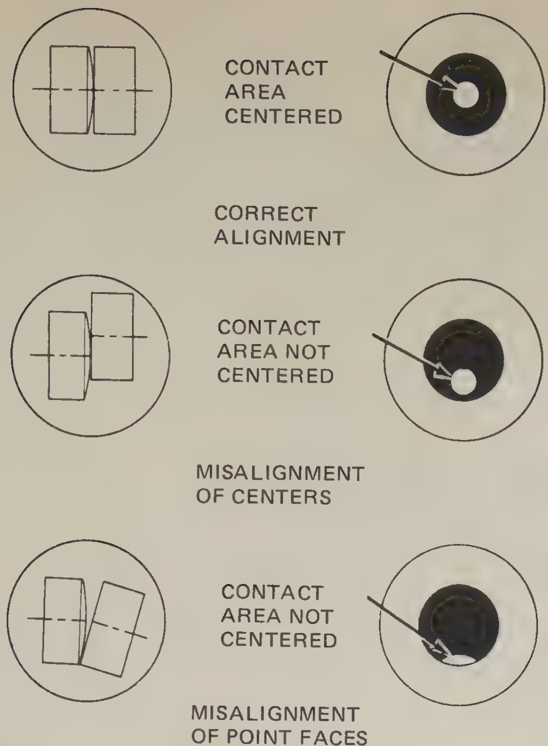


FIG. 26-17 Correct and incorrect alignment of breaker points.

between the points (Fig. 26-18). Make sure the feeler gauge is clean so you do not get oil or dirt on the points. The thickness of the feeler gauge selected to make the measurement varies with different engines. Always check the specifications for the engine being checked.

Adjustments are made in different ways according to the method of point attachment. On some magnetos, the adjustment is made as shown in Fig. 26-18. The lock screw holding the bracket on which the stationary point is mounted is loosened slightly. Then a screwdriver is inserted into the slot and twisted to move the stationary point the correct amount to get

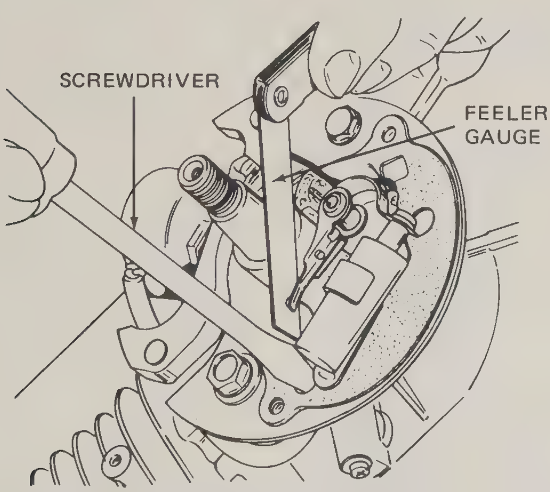


FIG. 26-18 Typical magneto breaker-point adjustment. (*Tecumseh Products Company*)

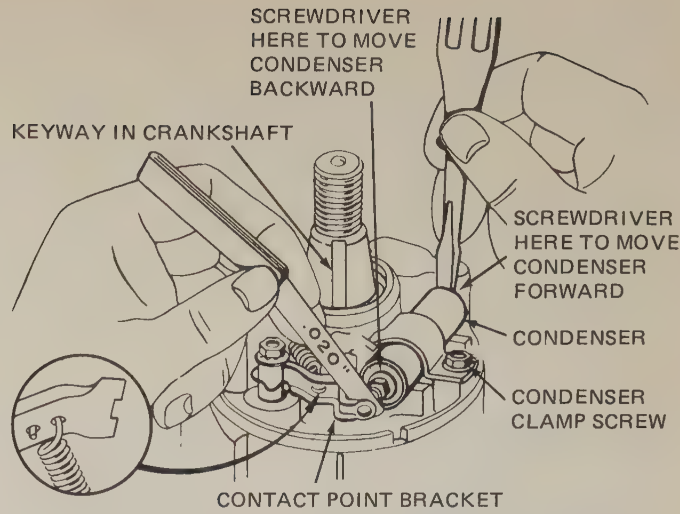


FIG. 26-19 With this arrangement, the point opening is adjusted by shifting the condenser one way or the other. (*Briggs & Stratton Corporation*)

the proper point opening. Then the lock screw is tightened.

Another point arrangement is shown in Fig. 26-19. With this arrangement, the stationary point is mounted on the end of the condenser. To make the adjustment, the condenser-clamp screw is loosened slightly. Then the condenser is shifted one way or the other with the screwdriver to get the proper point opening.

In the arrangement shown in Fig. 26-20, the stationary point is mounted on a bracket. The lock screw must be loosened to shift the bracket as necessary to get the proper point opening. Then the lock screw is tightened.

○ 26-5 TIMING THE IGNITION To time the ignition means to make an adjustment that will cause the spark to occur at exactly the right time before the piston reaches TDC on compression. This starts the ignition process at the correct moment so that maximum power will be realized on the power stroke. If the timing is early, the engine will backfire on start-

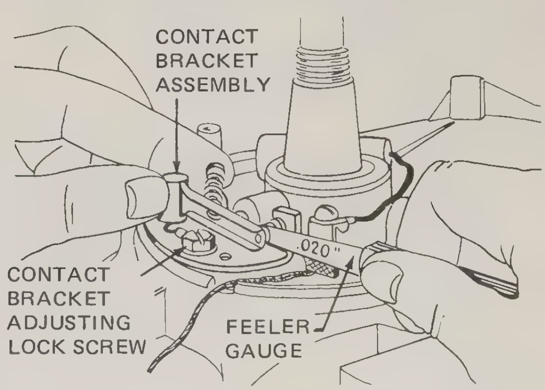


FIG. 26-20 In this magneto, the point opening is adjusted by loosening the lock screw and shifting the bracket on which the stationary point is mounted.

ing and detonate when running. If the timing is late, the power stroke will be weak, because ignition will not start until after the piston has begun to move down on the power stroke.

Various methods of timing the ignition are used. On many engines, ignition can be timed either with the engine not running (static timing) or with the engine running.

The sequence shown in Fig. 26-21 shows the static ignition-timing procedure for many small two-cycle engines. After installing the points (1), align them using the special tool shown to bend the stationary-point support (2). Then measure the point opening and adjust it as required (3). Next, clean the points with lint-free paper (4), and use a timing tool or rule to locate the TDC position of the piston, as shown at (5) and (6). Back off the piston by turning the crankshaft backwards (7). Find the timing dimensions in the manufacturer's specifications, and adjust the tool to that dimension. Then tighten the thumb screw to lock

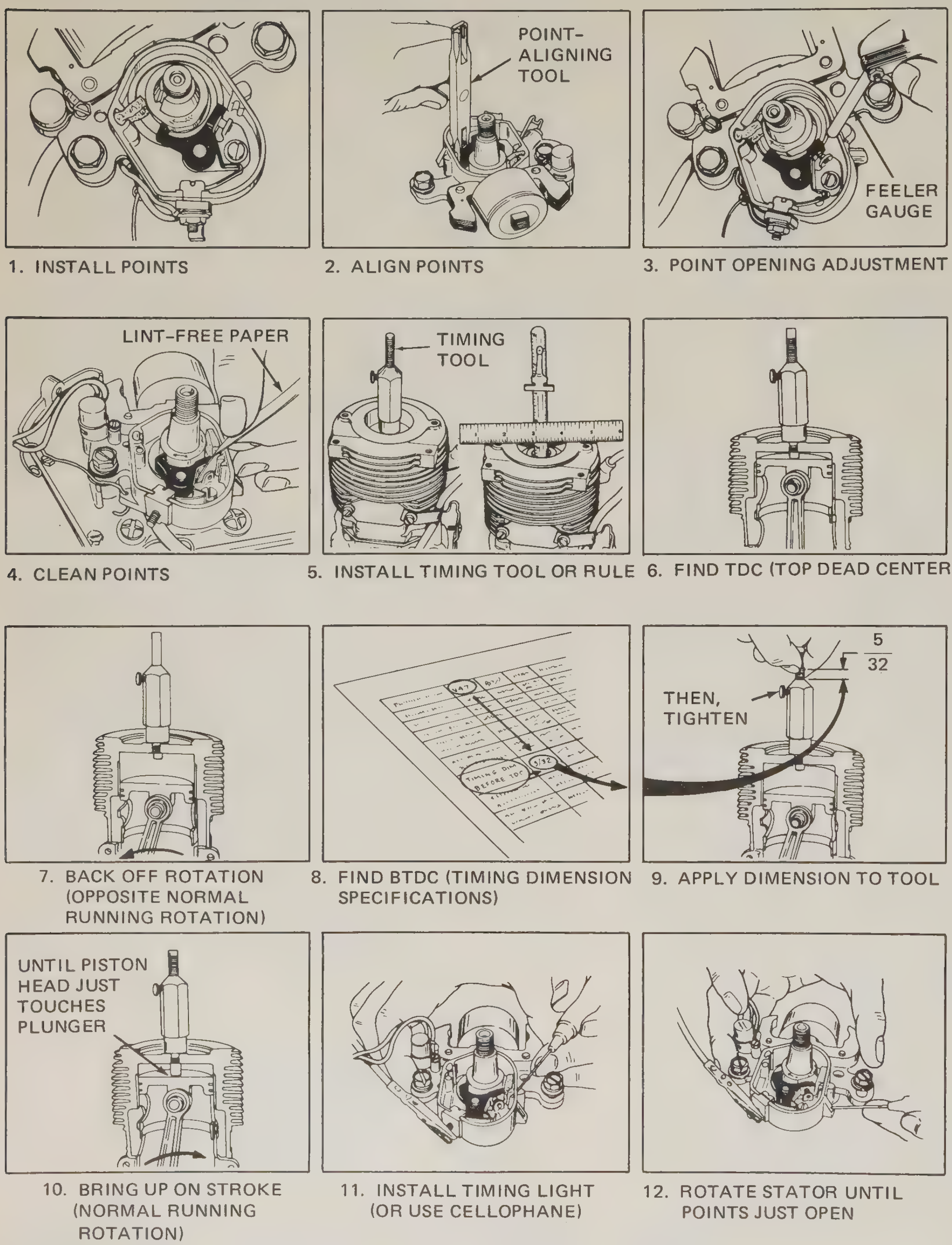


FIG. 26-21 The complete sequence of actions to time one line of two-cycle engines. (*Tecumseh Products Company*)

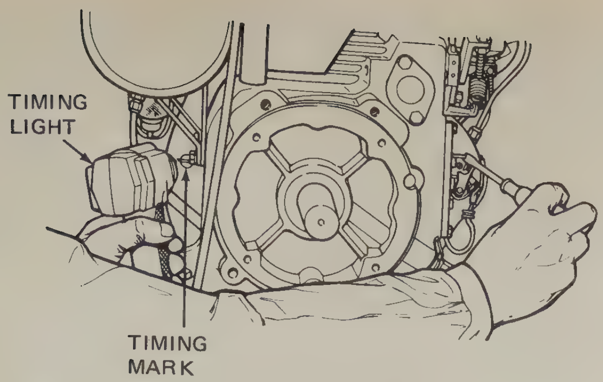


FIG. 26-22 Using a stroboscopic timing light to time the ignition. (*Kohler Company*)

the dimension, as shown in (8) and (9). Next, slowly rotate the crankshaft in the normal running direction until the piston touches the bottom of the tool (10). Then install a test light, connected across the contact points (11). With the stator hold-down screws loosened slightly, shift the stator as shown in (12) until the points just open. When this occurs, the light goes out. Tighten the hold-down screws. As an alternative, you can use a strip of thin cellophane between the points, and this will fall out as the points separate. After completing the timing, install lead, cover, flywheel, and lower housing.

Figure 26-22 shows how to time a running engine by using a timing light. The timing light is connected to the spark-plug cable. Each time the plug fires, a momentary flash of light is produced by the timing light. During the timing operation, the light is directed to a hole in the engine case through which the flywheel can be seen. The flywheel has a timing mark on it that should align with a mark on the case when the timing is correct. If the marks do not align, adjustment is made by loosening the point-opening adjusting screw. Then shift the breaker plate with a screwdriver, as shown to the right in Fig. 26-22. When the marks align, tighten the breaker-plate screw. Ignition timing is checked and set with the engine running at a specified speed. For the engine shown in Fig. 26-22, the specified speed is 1200 to 1800 revolutions per minute (rpm).

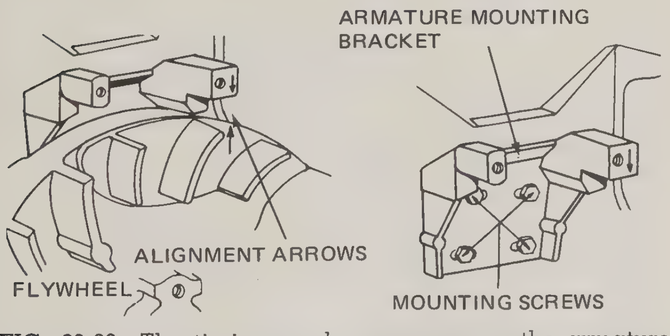


FIG. 26-23 The timing marks or arrows on the armature mounting bracket and flywheel. (*Briggs & Stratton Corporation*)

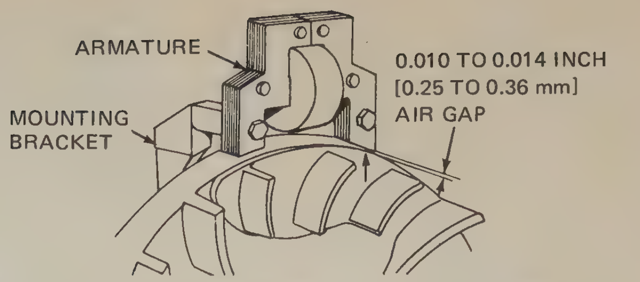


FIG. 26-24 The correct armature air gap is set on this model by shifting the armature up or down as necessary. (*Briggs & Stratton Corporation*)

Some engines have timing marks on the armature mounting bracket and flywheel, as shown in Fig. 26-23. To time the ignition on these engines, remove the flywheel, set the points to the proper opening, install the flywheel, and run the nut on finger-tight. Then rotate the flywheel in the running direction until the points are just opening. Next, take off the flywheel, being very careful not to move the crankshaft. Note the positions of the arrows. If they do not align, slightly loosen the mounting screws holding the armature bracket to the engine cylinder. Slip the flywheel back on the crankshaft, using the key to get correct alignment. Install the flywheel nut finger-tight.

Now move the armature and bracket assembly to align the arrows. Remove the flywheel and tighten the armature-bracket mounting screws. Install the flywheel, with the key, and tighten the nut to the specified torque. Finally, set the armature air gap to the proper specifications, as shown in Fig. 26-24. Loosen the two armature attaching screws, and move the armature up or down as necessary. A simple way to set the proper air gap is to put a postcard between the armature and the flywheel. Set the armature down against the postcard. Then tighten the attaching screws and remove the postcard.

○ 26-6 CHECKING MAGNETO PARTS Besides the breaker points, other components of the magneto which need to be checked are the magnets on the flywheel, the magneto coil, and the condenser. A coil-condenser tester used to test automotive-type ignition coils will also test magneto coils. The condenser is checked for capacity, insulation resistance, shorts or grounds, and high series resistance. If the condenser does not meet specifications on any of these tests, it should be replaced.

The magneto coil should be inspected for damage and tested on a coil tester. If the coil fails to meet specifications, it should be replaced.

The magnets on the flywheel can be tested to see whether they are still strong enough to produce adequate magnetism. One test is to lay the flywheel on a flat wooden surface and hold a screwdriver about 1 inch [25 mm] from the magnets, as shown in Fig. 26-

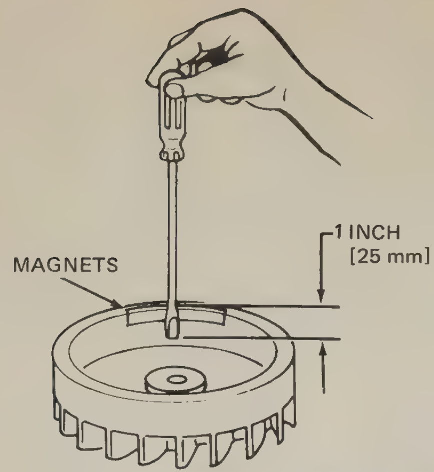


FIG. 26-25 Testing the strength of the flywheel magnets. (*Tecumseh Products Company*)

25. The magnets should be strong enough to pull the tip of the screwdriver into them. If the magnets are weak, they should be replaced or remagnetized on a special magnetizer. Alnico magnets cannot be recharged and must be replaced with new magnets if the old ones have lost strength. Never store flywheels in nested piles. This can cause the magnets to lose their strength.

○ 26-7 SPARK-PLUG SERVICE Spark plugs may fail for a variety of reasons. They are subjected to high temperatures, high pressures, and high voltages. Spark plugs must withstand these conditions and must also operate at the proper temperature. If a plug becomes too hot, it will wear rapidly and may burn. If it does not become hot enough, it may foul, since oil and fuel soot or carbon may deposit on it. If enough material is deposited, then the high-voltage current will leak to ground through the deposit instead of jumping the spark gap. Then the plug will not fire and the engine will miss.

The temperature the plug reaches is governed by the heat range of the plug. Heat range is a function of the shape of the plug and the distance heat must travel from the center electrode of the plug to reach the cylinder head (Fig. 26-26). If the path that the heat must travel is long, then the plug will run hot. If it is short, the plug will run cool.

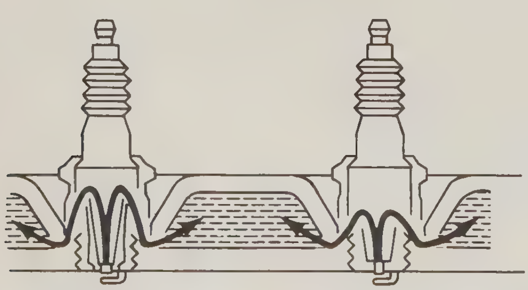


FIG. 26-26 The heat range of spark plugs. The longer the heat path (indicated by the arrows), the hotter the plug runs. (*AC Spark Plug Division of General Motors Corporation*)

Spark plugs have a tough job. They take the repeated high-voltage surges that produce the sparks, as well as the tremendous heat and pressure pulses when ignition takes place. Yet they will work satisfactorily for many hours. Plugs in small engines should be checked and serviced or replaced periodically in order to maintain top engine performance. There are spark-plug cleaners which will clean the plug with a blast of abrasive sand against the electrodes and porcelain interior (Fig. 26-27). The spark plug is put into the cleaner. The cleaner sends a blast of grit against the electrodes and insulator to clean them. Some manufacturers, however, warn against using a sand-blast spark-plug cleaner and void the warranty on their engine if a sand-blasted spark plug is installed in it. Their reasoning is that it is difficult to remove all traces of sand and that an engine can be ruined by only a little sand in it.

You can also clean deposits out of the plug with a small-bladed knife, as shown in Fig. 26-28. Be careful to avoid damaging the porcelain insulator surrounding the center electrode and to remove all traces of sand or loosened deposits.

You can tell from its appearance whether a plug is of the correct heat range for the application. Figure 26-3 illustrates several spark-plug conditions and explains their causes. If a plug is operating too cold, there will be a sooty deposit on the insulator around the center electrode. If the plug is not hot enough, it cannot keep this deposit burned away. Even with a plug of the heat range specified for the engine, a deposit may form if (1) the air-fuel mixture is excessively rich (from excessive choking, worn carburetor jets, and so on) or (2) excessive amounts of oil enter the combustion chamber (due to such conditions as worn rings or cylinder walls, excessive intake-valve-stem clearance, and incorrect oil-fuel mixture). In such cases, a hotter plug would help prevent formation of excessive deposits on the plug. But it would not cure the basic trouble with the engine.

If the plug runs too hot, a white or grayish cast will appear on the insulator, and the insulator may also appear blistered. A plug that runs hot will wear more rapidly. The electrodes will burn away more rapidly. One cause of high plug temperature, aside from improper heat range, is incorrect installation of the plug in the engine. If the plug is not tightened to the correct torque, the plug gasket will not be sufficiently compressed. When this happens, the heat path is restricted. Therefore, the plug will run hotter. High temperature may result also if the plug seat in the cylinder head is not cleaned before the plug is installed. Dirt could block off the heat path and cause a hot-running plug. On some engines, the plugs do not use gaskets. The seating faces (on plug and head) must be clean and smooth to form a good seal and

FIG. 26-27 Spark-plug cleaner and tester. (*Champion Spark Plug Company*)

heat path. Cracked insulators usually are caused by careless installation or by improper adjustment of the plug gap.

After cleaning the plug, regap it. Measure the gap between the electrodes. Do not use a flat gauge, because this would result in too great a gap. Figure 26-29 shows how to check and adjust the spark-plug gap.

If you are having plug trouble, refer to Fig. 26-3 to diagnose the cause. This illustration will give you a clue as to what causes various kinds of plug trouble so that you can make corrections. If the old plug is in doubtful condition, however, the high cost of labor and the relatively low cost of spark plugs has caused many service technicians to recommend installing a new plug, rather than trying to service the old plug.

○ 26-8 SERVICE OF EXTERNALLY MOUNTED MAGNETOS In normal service, magnetos should not need adjustment. They are properly adjusted before the engine is shipped from the factory. However, the magneto is often blamed for almost any engine problem. Before the magneto is condemned and steps are undertaken to adjust or repair it, be sure that the problem really is with the magneto.

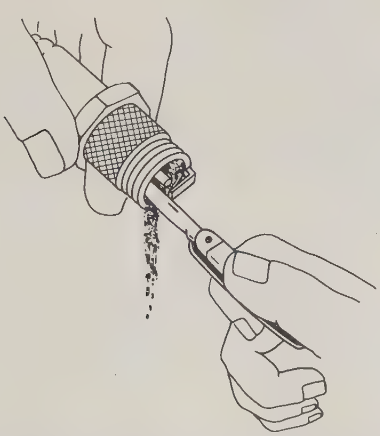


FIG. 26-28 Cleaning carbon from the spark-plug shell with a sharp knife.

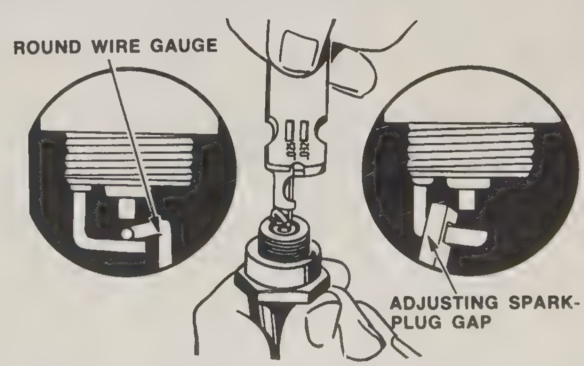


FIG. 26-29 Using a round wire gauge and adjusting tool to adjust the spark-plug gap.

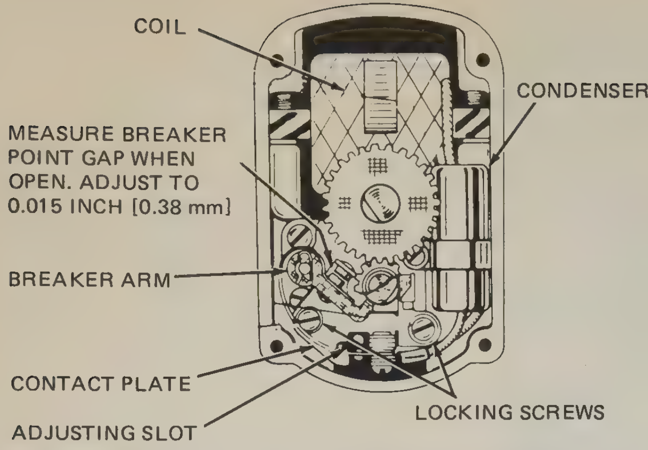


FIG. 26-30 The end view of an externally mounted magneto with the end cap removed. (*Wisconsin Motor Corporation*)

A quick check of a magneto is to perform the spark test. Remove the spark-plug cable from the spark plug, and hold the metal terminal about 3/16 inch [5 mm] from the cylinder head. Then crank the engine at least two complete revolutions and watch for a strong spark. Most externally mounted magnetos use an impulse coupling, so the spark should occur at the instant the impulse coupling snaps. On a multicylinder engine, repeat this test with each spark-plug cable. If there is no spark or a weak spark, the breaker points in the magneto must be checked.

To check the breaker points, first remove the magneto end cover, or cap. See Fig. 26-30. If the contact points are dirty, clean them with solvent and a cloth. If the points are slightly pitted, clean the points with an ignition file. Severely pitted points must be replaced.

Any time the contact points are filed, the point opening must be reset. Check the specifications for the engine you are servicing. Many externally mounted magnetos for small engines use a 0.015-inch [0.38-mm] point opening. To set the point opening, crank the engine until the points are wide open on the high part of the magneto cam lobe. Then loosen the lock screws with a screwdriver until the contact plate can be moved. Place the blade of the screwdriver in the adjusting slot, shown in Fig. 26-30. Move the contact plate until the proper clearance can be measured with a feeler gauge between the open contact points. Then tighten the locking screws. After tightening the plate, make a quick check of the point opening to make certain that it did not change as the plate was tightened.

When the contact points are badly pitted or worn, they must be replaced. Contact points should be replaced as a set. Replace both the movable point and the stationary point at the same time. To replace the points, first remove the spring-contact screw (Fig. 26-31). Then remove the breaker-arm lock and washer, and lift the breaker arm off of the pivot post. With a screwdriver, remove the two lock screws from the breaker plate. Remove the stationary point, and wipe the distributor plate clean with a cloth.

Install the points and adjust the point opening, as discussed earlier. In many magnetos a wick is used to lubricate the cam. Replace the cam wick with a

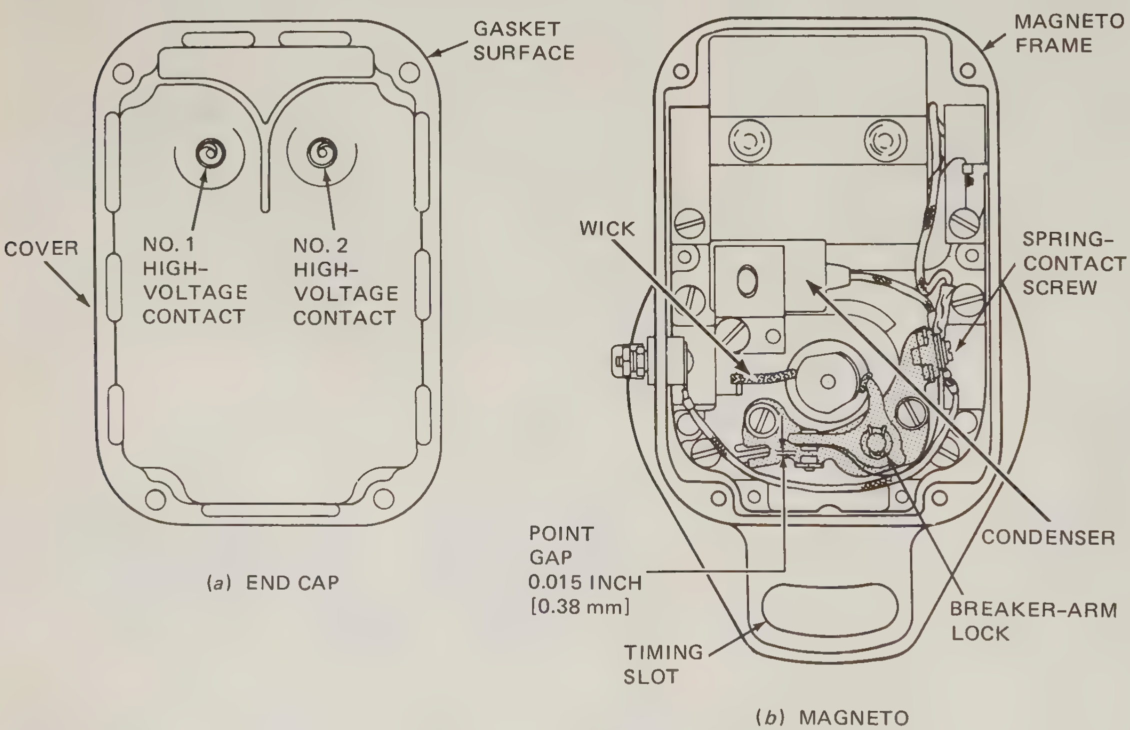


FIG. 26-31 The magneto for a two-cylinder four-cycle engine, with end cap removed. (*Kohler Company*)

new one. Lubricate the wick with the recommended type of oil or grease if specified in the operator's manual.

When the magneto end cap or cover has been removed, it must be replaced carefully. The magneto is a sealed unit. This is one reason for its reputation as having a long, trouble-free life. To properly reseal the end cover, clean the surface on the cover and on the magneto frame. Then install the end cover, using a new gasket. Some manufacturers recommend sealing the end cover with a gasket sealer such as Permatex. Do not overtighten the cover screws, as the cover may crack. No other service of the magneto is recommended. However, the coil and condenser can be checked with a coil-condenser tester.

○ 26-9 TIMING THE MAGNETO Many externally mounted magnetos have the drive gear mounted at the end of the rotor shaft on the impulse coupling (Fig. 26-32). To replace the drive gear on certain magnetos, the following procedure must be followed to avoid installing the gear 180° off. Remove the end cover and turn the rotor until it is in the No. 1 cylinder firing position. This is shown in the right part of Fig. 26-32. Notice that the drive gear has a punch mark on one gear tooth. Place the drive gear on the impulse-coupling lugs with the punch mark located as shown in the left part of Fig. 26-32.

When the magneto has been removed from the engine, the magneto must be properly timed during installation. Remove the screws holding the flywheel air-intake screen in place, and remove the screen from the engine. With the screen off, you can see the timing marks on the flywheel and shroud. Remove the spark plug from the No. 1 cylinder. Slowly crank the engine while holding a finger over the spark-plug hole. When you feel air blowing from the hole, stop turning the engine. Now, very slowly, turn the engine until the timing marks align. Then reinstall the spark plug.

To determine the No. 1 cylinder firing position of the magneto, insert the spark-plug cable in the No. 1 tower of the magneto cap. Then hold the metal clip at the other end of the spark-plug wire close to the metal frame of the magneto. Turn the magneto gear in its normal direction of rotation until a spark jumps from the No. 1 spark-plug cable to the magneto. This is the No. 1 cylinder firing position. Holding the magneto drive gear in this position, install the magneto, making sure that the magneto flange gasket is in place. Be sure to mesh the gears so that the marked tooth is properly positioned. Then tighten the magneto to the gear cover. Check the ignition system by turning the crankshaft and checking for a spark by making a spark test. Then start the engine. On some engines, after the magneto is installed and the engine is running, the timing and the spark advance are checked with a timing light (Fig. 26-22). If required, the timing is adjusted to specifications.

To change the timing, loosen the bolts holding the magneto to the engine. Then shift the position of the magneto until the timing mark is properly positioned. In Fig. 26-33, there is a timing slot in the magneto for this purpose. Shifting the magneto in the direction that the drive gear and shaft are rotating retards the timing. Moving the magneto in the opposite direction to its rotation advances the timing. When the timing is correct, tighten the mounting bolts.

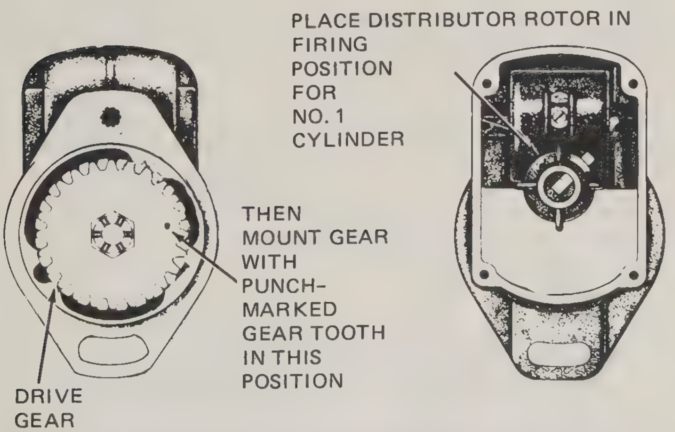
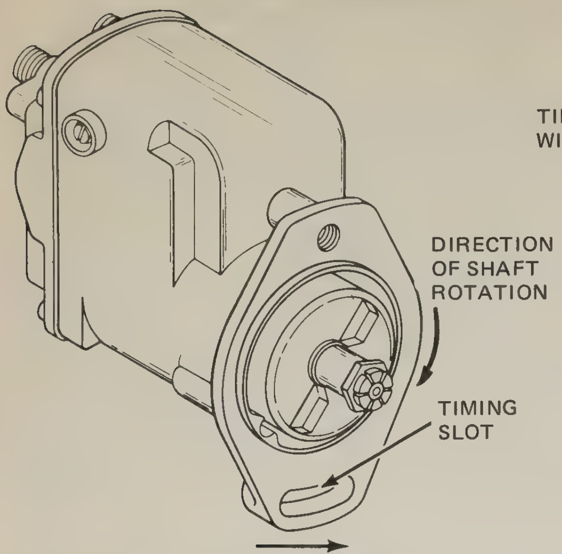


FIG. 26-32 The marking and position of the drive gear on the magneto rotor shaft. (*Wisconsin Motor Corporation*)

○ 26-10 TROUBLESHOOTING THE BATTERY IGNITION SYSTEM In this part of the chapter, you will learn the various causes of battery-ignition-system troubles.

Ignition system failures can be grouped into three categories as follows:

1. Loss of energy in the primary circuit. This, in turn, may be caused by several conditions:
   a. Resistance in the primary circuit due to defective leads, bad connections, burned distributor contact points or switch, or open-coil primary winding
   b. Points not properly set
   c. Discharged battery or defective alternator
   d. Defective condenser (shorted, low insulation resistance, or high series resistance)
   e. Grounded primary circuit in coil, wiring, or distributor
   f. Defective electronic control unit or pickup-coil circuit
2. Loss of energy in the secondary circuit. Possible causes are as follows:
   a. Plugs fouled, broken, or out of adjustment
   b. Defective high-voltage wiring which allows high-voltage leaks
   c. High-voltage leakage across coil head, distributor cap, or rotor
   d. Defective connections in high-voltage circuits



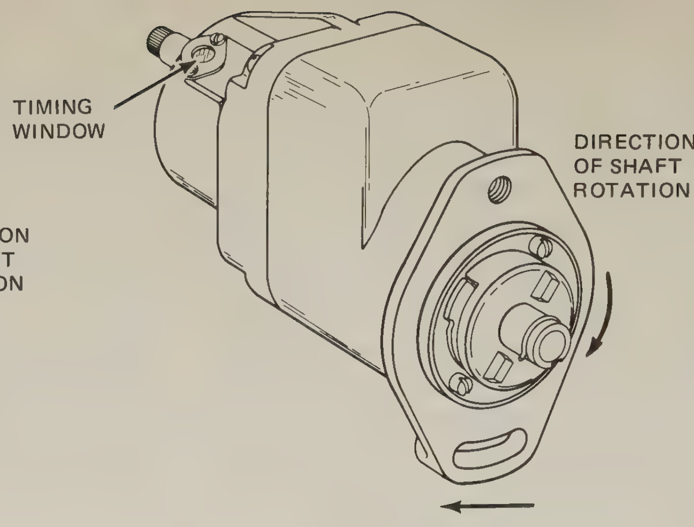


FIG. 26-33 (*a*) Shift the magneto opposite the direction of its rotor rotation to advance the timing. (*b*) Shift the magneto in the direction of rotor rotation to retard the timing. (*Kohler Company*)

3. Out-of-time ignition. Possible causes are as follows:
   a. Timing not set properly
   b. Distributor bearing or shaft worn, or shaft bent
   c. Centrifugal advance defective
   d. Preignition, due to spark plugs of wrong heat range, fouled spark plugs, etc.

Table 26-1 is a troubleshooting chart which lists (1) various ignition-system troubles and possible engine troubles that might originate in the ignition system, (2) possible causes of these various troubles, and (3) checks or corrections to be made.

There are several quick checks that can be made when certain types of troubles occur. These quick checks often immediately indicate the cause of trouble. However, it may be necessary to use special test instruments to find the cause. If an oscilloscope is available and the engine can be started, the oscilloscope can pinpoint many trouble causes in the ignition system. Often the first step in finding the source of the problem will be to recharge the battery, since the operator may have run it down in a vain attempt to start. Quick checks to be made and causes and corrections of various ignition troubles are described below.

○ 26-11 FINDING SOME BATTERY-IGNITION-TROUBLE CAUSES Now let us examine in detail the various troubles and their causes listed in the troubleshooting chart. Some of these troubles can occur only in multicylinder engines.

Engine Cranks Normally but Will Not Start If the engine can be cranked at normal cranking speed but will not start, the trouble is probably in the ignition system or the fuel system. First, test the ignition system by trying the spark test. Disconnect the lead from one spark plug. Hold the lead clip about 3/16 inch [5 mm] from the engine block while cranking the engine, as shown in Fig. 26-34. Another way is to pull the lead from the center terminal of the distributor cap and hold it close to the engine block. If a good spark jumps to the block, the chances are that the primary and secondary circuits are in good condition. These circuits must both function normally to produce a good spark. If they do, then failure to start could be due to badly fouled spark plugs or out-of-time ignition. However, many other conditions including faulty fuel-system action, malfunctioning valves, and loss of engine compression could prevent normal starting. Failure to start with normal cranking usually is due to trouble in the ignition or fuel system.

One condition that sometimes prevents starting on humid or rainy days is that of moisture collecting on the spark-plug insulators. The moisture allows the

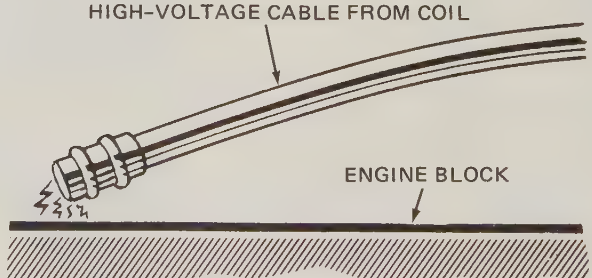


FIG. 26-34 Make a spark test by holding the high-voltage cable about 3/16 inch [5 mm] from the engine block.

TABLE 26-1 BATTERY-IGNITION-SYSTEM TROUBLESHOOTING CHART

Condition	Possible Cause	Check or Correction
1. Engine cranks normally but will not start	a. Open primary circuit	Check connections, coil, contact points, and switch for open
	b. Coil primary grounded	Replace coil
	c. Points not opening	Adjust
	d. Points burned	Clean or replace
	e. Out of time	Check and adjust timing
	f. Condensor defective	Replace
	g. Coil secondary open or grounded	Replace coil
	h. High-voltage leakage	Check coil head, distributor cap, rotor, and leads
	i. Spark plugs fouled	Clean and adjust or replace
	j. Defects in electronic control unit or pickup-coil circuit	Replace defective part
	k. Fuel system faulty	Check
	l. Engine faulty	Repair engine
2. Engine runs but misses—one cylinder	a. Defective spark plug	Clean or replace
	b. Distributor cap or lead defective	Replace
	c. Engine defects such as stuck valve, defective rings, piston, gasket	Repair engine
3. Engine runs but misses—different cylinders	a. Points dirty, worn, or out of adjustment	Clean, replace, or adjust as necessary
	b. Condenser defective	Replace
	c. Advance mechanism defective	Repair or replace distributor
	d. Defective high-voltage wiring	Replace
	e. Defective (weak) coil	Replace
	f. Bad connections	Clean and tighten connections
	g. High-voltage leakage	Check coil head, distributor cap, rotor, and leads
	h. Defective spark plugs	Clean, adjust, or replace
	i. Defective fuel system	Check
	j. Defects in engine such as loss of compression or faulty valve action	Repair engine
4. Engine lacks power	a. Timing off	Retime ignition
	b. Exhaust system clogged	Clear
	c. Excessive load resistance	Check load
	d. Heavy engine oil	Use correct oil
	e. Wrong fuel	Use correct fuel
	f. Engine overheats	See item 5
	g. Other defects listed under item 3	
5. Engine overheats	a. Late ignition timing	Retime ignition
	b. Lack of coolant or other trouble in cooling system	See previous chapter on cooling systems
	c. Late valve timing or other engine conditions	Repair engine
6. Engine backfires	a. Ignition timing off	Retime ignition
	b. Ignition cross-firing	Check high-voltage wiring, cap, and rotor for leakage points
	c. Spark plugs of wrong heat range	Install correct plugs
	d. Engine overheating	See item 5
	e. Fuel system not supplying proper air-fuel ratio	Check as explained in previous lesson
	f. Engine defects such as hot valves or carbon	Repair engine

TABLE 26-1 BATTERY-IGNITION-SYSTEM TROUBLESHOOTING CHART (Continued)

Condition	Possible Cause	Check or Correction
7. Engine detonates or pings	a. Improper timing	Retime engine
	b. Advance mechanisms faulty	Rebuild or replace distributor
	c. Points out of adjustment	Readjust
	d. Distributor bearing worn or shaft bent	Rebuild or replace distributor
	e. Spark plugs of wrong heat range	Replace with correct plugs
	f. Low-octane fuel	Use fuel of proper octane
	g. Conditions listed under item 6	
8. Rapid wear of centrifugal-advance mechanism	a. Loose or worn valve-timing gears	Repair
	b. Worn oil pump	Repair
9. Pitted contact points	a. Transfer of point	Buildup on positive point: install new condenser with higher capacity; separate leads or move closer to ground; shorten condenser lead. Buildup on negative point: install new condenser with lower capacity; move leads closer together or away from ground; lengthen condenser lead
10. Burned or oxidized contact points	a. Excessive resistance in condenser circuit	Tighten condenser mounting and connection; replace condenser if bad
	b. High voltage	Readjust voltage regulator
	c. Excessive dwell, too little gap	Reset contact points
	d. Weak spring tension	Adjust contact-spring tension
	e. Oil or crankcase vapors entering distributor	Check engine PCV system; avoid overlubricating distributor
11. Spark plug defective	a. Cracked insulator	Install new plug
	b. Spark plug sooty	Install hotter plug; correct condition in fuel system or engine causing high fuel consumption
	c. Spark white or gray, with blistered insulator	Install cooler plug

high-voltage current to leak to ground instead of jumping the spark gap. No ignition occurs, and the engine will not start. However, if the moisture is wiped from the spark-plug insulators, a normal start usually can be made.

Another way of checking for a spark is to remove the distributor cap and snap the contact points open and closed. The ignition switch should be on, and the lead from the coil high-voltage terminal should be held close to the engine block. This check does not test the distributor drive or the secondary wiring.

If a spark does not occur when the spark test is made, it means the ignition system is not doing its job of producing high voltage. Make the following additional test, watching the instrument-panel ammeter while cranking. If the engine does not have an ammeter, connect a test ammeter into the ignition primary circuit to make this test.

1. If there is a small reading which fluctuates somewhat during cranking, then the primary circuit is probably in good condition. The trouble most likely is in the secondary and is due to a defective coil secondary, defective secondary connections or leads, or high-voltage leakage across the coil head, cap, or rotor. Also, an open or "weak" condenser could be preventing high-voltage buildup in the secondary.
2. If the ammeter shows a fairly high and steady discharge reading with no fluctuations during cranking, then the trouble is probably in the primary circuit. Either the points are not opening because they are out of adjustment or the condenser is grounded, or else the primary circuit is grounded in the coil or primary winding.
3. If there is no ammeter reading, the primary circuit is open. The open could be due to a loose connection, defective wiring or switch, distributor contact points out of adjustment or burned, or an open coil primary. A voltmeter can be used to find the open by checking from various terminals in the primary to ground to see where voltage is available. If there is voltage here, the trouble is inside the distributor. If there is no

voltage at the distributor primary-lead terminal on the coil, check from the other ignition-coil primary terminal to ground. If you now get a reading, the trouble is in the coil primary winding. If you get no reading, the trouble is in the wiring or the switch. Disassemble the switch extension if the coil has one, so that the coil and switch may be checked separately.

Engine Runs but Misses—One Cylinder You can locate a missing cylinder on a multicylinder engine. Use a screwdriver to short out each cylinder spark plug in turn with the engine running at various speeds (Fig. 26-35). The screwdriver should have an insulated handle so that you do not get shocked. Short out the spark plug by putting the screwdriver from the spark-plug terminal to the cylinder block. This prevents a spark from occurring in the spark plug and causes the cylinder to miss.

On some engines, the spark plugs have neoprene boots over the spark-plug terminals. It is difficult to short out these plugs. Instead, remove the cables from the distributor cap one by one and note any change in engine speed. If the engine rhythm or speed changes when the plug is shorted out or its circuit is opened, then that cylinder was delivering power before being shorted out. However, if no change in the operation of the engine is noted when a spark plug is shorted out or its circuit is opened, then the cylinder is not delivering power. It is missing.

If you locate a missing cylinder, remove the lead from the spark plug, with the other cylinders operating, and hold it close to the engine block to see if a good spark occurs. If it does not, the cause of trouble is in the secondary circuit of the ignition system. It could be due to defective cable insulation or to a cracked or burned distributor cap. Either of these conditions could allow high-voltage leakage to ground. But, if a good spark occurs, then it could be that the spark plug is defective. Install a new plug. If the cylinder now performs normally, the trouble was a defective plug. If changing the plug does not help, then the trouble is in the engine cylinder (stuck valve, defective rings, piston, head gasket, and so on).

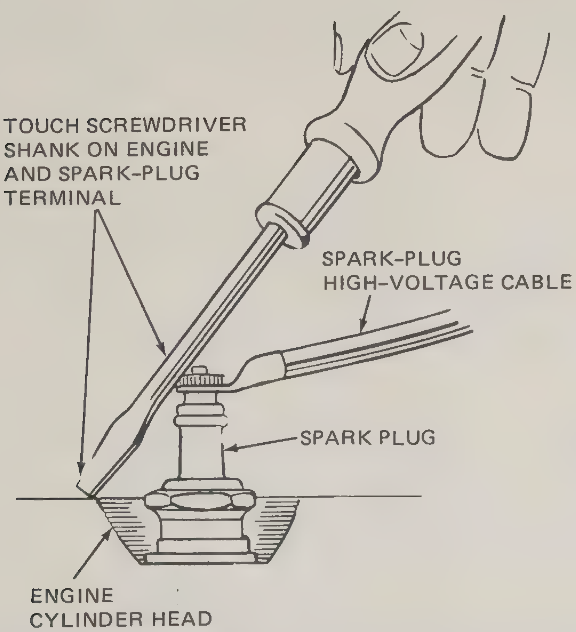


FIG. 26-35 Use a screwdriver to short out each spark plug in turn.

Engine Runs but Misses—Different Cylinders If the miss seems to jump around and you cannot pin it down to any particular cylinder, the trouble could be due to any of several conditions in the ignition system, fuel system, or engine. The distributor contact points could be worn, dirty, or out of adjustment. The condenser or ignition coil could be "weak," so that the spark would not be uniform and erratic missing would occur. The advance mechanisms might be erratic in action and thus cause uneven timing and missing. Distributors with the breaker plate supported by balls running in a ball track in the distributor housing may have the following troubles: the ball track may wear, or the balls may get dirty or worn. This causes the breaker plate to hang up or tilt when the vacuum-advance mechanism operates, which then causes a momentary erratic miss.

Bad ignition-circuit connections or defective wiring can also cause missing. If high-voltage leakage occurs across the coil head, distributor cap, or rotor, or if there is leakage through secondary-wiring insulation, missing may occur. Long-continued leakage across the coil head or the rotor will etch a visible path. If this occurs, the part will require replacement. Otherwise, wiping dirt from the part and keeping it clean and dry will prevent such leakage. If the insulation on the secondary wiring has deteriorated or is cracked or rotting, it may allow high-voltage leakage. This condition requires replacement of the wiring.

Installing a coil with incorrect connections so that the secondary polarity is reversed could increase the voltage requirements so much that missing would result. The reversed connections mean that the electrons must jump from the relatively cool outer electrode to the center electrode. This requires a considerably higher secondary voltage and increases the possibility of engine missing, especially at high speeds. Normally, the coil is connected so that the electrons jump from the hot center electrode to the cooler outer electrode. With the emitting electrode hot, voltage requirements are considerably lower.

To test for reversed polarity, hold an ordinary pencil tip between the high-voltage-wire clip and the spark-plug terminal, as shown in Fig. 26-36. The spark should flare out between the pencil tip and the spark plug. If the spark flares out between the pencil tip and the wire clip, the polarity is reversed. Another

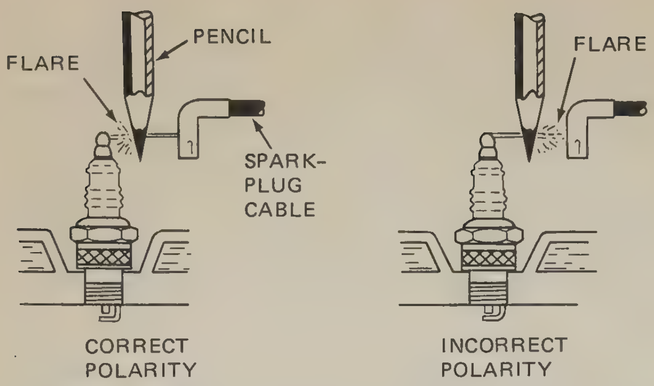


FIG. 26-36 Using a pencil tip to check the polarity of the ignition coil. If the flare is between the pencil tip and the high-voltage-lead clip, and not as shown, the coil is connected backwards. (*Champion Spark Plug Company*)

test is to connect a neon bulb (NE-2 or similar) between the spark-plug terminal and ground. With the engine running, the end of the neon bulb connected to the spark-plug terminal should glow. If the end connected to ground glows, the polarity is reversed.

Worn or fouled spark plugs will miss, especially during a heavy load or on acceleration. Many other conditions in the engine and fuel system could cause missing. If the fuel system fails to deliver an air-fuel mixture of the proper proportions, or if the engine has faulty valve action or loss of compression, missing will occur.

Engine Lacks Power Many conditions can cause lack of power. With the timing off or with any of the conditions discussed previously under "Engine Runs but Misses," the engine will not deliver normal power. In addition, if the exhaust system is clogged, if heavy engine oil or the wrong fuel is being used, or if there is excessive load resistance due to a dragging generator-set armature, then the engine will seem sluggish and lacking in power.

Engine Overheats Engine overheating may be caused by many conditions in the engine cooling system or in the engine itself. It can also be caused by late ignition timing.

Engine Backfires Backfiring can be caused by several conditions in the ignition system. If the ignition timing is considerably off or if ignition cross-firing occurs as a result of spark jumpover from one terminal or spark-plug lead to another, ignition may result before the intake valve closes. This causes a backfire.

If a spark plug runs too hot, it may glow enough to ignite the air-fuel mixture before the intake valve closes. Install a colder spark plug.

Engine Detonates or Pings Spark knock (detonation or ping) often is blamed on the ignition system. But there are many other conditions that will cause detonation in the engine. These include excessively advanced timing, faulty advance mechanisms which cause excessive advance, out-of-adjustment points, distributor bearing worn or shaft bent which causes excessive advance to some cylinders, spark plugs of wrong heat range which glow and cause preignition, and so on. Other causes of detonation or ping include fuel with an octane rating too low for the engine and type of operation, excessive carbon in the engine combustion chambers, and conditions listed previously under "Engine Backfires." Of all these conditions, the most usual causes of pinging are excessive ignition advance and gasoline with an octane rating too low for the engine and operating conditions.

There are other kinds of engine knock, not caused by ignition problems. For example, worn bearings, cylinders, and pistons can cause various kinds of mechanical knock in an engine.

Rapid Wear of Centrifugal-Advance Mechanism Rapid wear of the centrifugal-advance mechanism will occur on certain engines as a result of loose or worn valve-timing gears or a worn oil pump. Either of these conditions causes backlash and torsional vibration in the distributor drive. This, in turn, wears the centrifugal-advance mechanism rapidly.

Pitted Contact Points Some arcing across the contact points will occur in spite of condenser action. Under some conditions, this arcing may cause point pitting. Pitting is due to the transfer of point material from one contact to the other. A pit is left in one contact, and there is a matching buildup of material on the other contact. Normally, the system is balanced, so pitting is at a minimum. But, under certain unusual conditions, it will occur. To correct point pitting if the negative point loses material with the buildup on the positive point, one or more of the following steps should be taken:

1. Install a new condenser with a higher capacity.
2. Separate the low- and high-voltage leads or move these leads closer to ground. This reduces the capacity effect between these leads.
3. Shorten the condenser lead if possible.

If the positive point loses material, the buildup is on the negative point. To correct this condition, install a new condenser with a lower capacity, move the leads closer together or away from ground, or lengthen the condenser lead.

Burned or Oxidized Contact Points Burning or oxidizing of contact points can be caused by several conditions:

1. Excessive resistance in the condenser circuit. This is detectable with a high-frequency condenser tester. The condition is corrected by either tightening the condenser mounting and connections or replacing the condenser, according to where the resistance is.

2. High voltage, which causes excessive current draw through the points. This can be detected by making a voltmeter check with the engine operating at medium speed. Correction may require adjustment of the voltage-regulator setting or reduction of alternator output.

3. Dwell too large, point opening too small. If points remain closed for too long a period of total operating time, they burn rapidly. This possibility requires checking the dwell or point opening, and adjusting as necessary.

4. Weak point-spring tension, which causes the points to flutter, bounce, and arc at high speeds. Measure the spring tension and adjust or replace the points.

5. Oil or crankcase vapors entering the distributor housing and depositing on the point surfaces, causing them to burn rapidly. A look at the breaker plate usually discloses this condition. The oil on the point surfaces (as it burns) causes a black smudge on the breaker plate under the point. A clogged engine crankcase ventilating system which forces oil into the distributor, excessive oiling of the distributor, or worn distributor bearings will produce this trouble.

Spark Plug Defective Spark plugs may fail for a variety of reasons. Should you find a spark-plug problem, review ○ 26-7, which concerns spark-plug service. The diagnosis of spark-plug troubles is shown in Fig. 26-3.

REVIEW QUESTIONS

1. How do you make a spark test?
2. What is the next step if no spark occurs on the spark test?
3. Where are the points located on an engine that has an internal magneto?
4. Describe the various ways that a flywheel can be removed from a tapered shaft.
5. Why should only a soft hammer be used to strike the flywheel nut?
6. What happens when the rubbing block on the breaker points wears?
7. Describe the procedure to adjust the breaker-point gap.
8. Explain how to set the timing on a two-cycle engine.
9. Why is the armature air gap important?
10. What is the typical armature air gap specification?
11. How can you make a quick check of the magnets in the flywheel?
12. What is a timing light?
13. Explain how to connect a timing light to a small engine.
14. What is spark-plug heat range?
15. What could happen to a two-cycle engine if too hot a spark plug is run in it?
16. Explain the steps in cleaning a spark plug.
17. Explain how to gap a spark plug.
18. What is an externally-mounted magneto?
19. How is the timing adjusted on an engine with an externally mounted magneto?
20. What are the three categories of battery-ignition-system failures?
21. What is dwell?
22. What happens to dwell when the breaker-point gap is changed?
23. What happens to the ignition timing when the breaker-point gap is changed?
24. How can you check the ignition system to determine if the ignition coil has been connected backwards?
25. What is the usual cause of a cracked insulator on a spark plug?

SELF PROJECTS

1. You should know how to use different kinds of ignition-system testing instruments. Here is one way to learn more about them: Get hold of the instruction sheet or booklet that accompanies each testing instrument in the shop. For example, the oscilloscope has a comprehensive instruction booklet. Study these booklets.

2. After studying each booklet, write brief summaries of how each test instrument is used. Note especially the cautions and the various test results, along with their meanings. File all your summaries in your notebook. You will then have a permanent record that tells you how to use the different test instruments. Furthermore, because you wrote these summaries yourself, you will understand the instructions better.

27
Chapter

Charging Systems

After studying this chapter, you should be able to:

1. **Explain why a charging system is needed**
2. **Describe the difference between a generator and an alternator**
3. **Describe the construction and operation of a generator**
4. **Describe the construction and operation of the starter-generator**
5. **Explain how generators are regulated**
6. **Describe the construction and operation of the flywheel alternator**
7. **Discuss how alternators are regulated**

○ 27-1 AC COMPARED TO DC The difference between alternating current (ac) and direct current (dc) is discussed in Chap. 20. Alternating current alternates in its direction of flow. In a conductor, it flows first in one direction and then in the other. This is shown in Fig. 20-7. Direct current flows in one direction only. All the devices in the small-engine electrical system require dc. (The exception is the ignition system, which was discussed in Chap. 25.) The battery requires dc for charging, for example. Since the current induced in the charging system (in the generator or alternator) is ac, it must be rectified or changed to dc.

○ 27-2 GENERATORS AND ALTERNATORS Generators and alternators are two different devices that do the same job: producing electric current. You will recall from Chap. 20 on basic electricity that electric current is a flow of electrons. When electrons are moving in one direction in a conductor, there is a flow of dc. When electrons flow first in one direction and then in the other in a conductor, there is a flow of ac.

In both the generator and alternator, ac is induced in the conductors. In the generator, one arrangement is used to rectify this ac, or change it to dc. In the alternator, a different arrangement is used to rectify the ac, or change it to dc. Some generators and alternators are built into the flywheel magneto. Others are separate units.

The two terms "generator" and "alternator" are sometimes used interchangeably. However, in this book, we will follow the style of the factory service manual: The generator uses brushes and a commutator. The alternator uses diodes. These terms are explained later in the chapter.

○ 27-3 GENERATOR PRINCIPLES The generator produces electricity by mechanical means. Mechanical motion is delivered to the generator by the engine. This motion causes conductors to cut through a

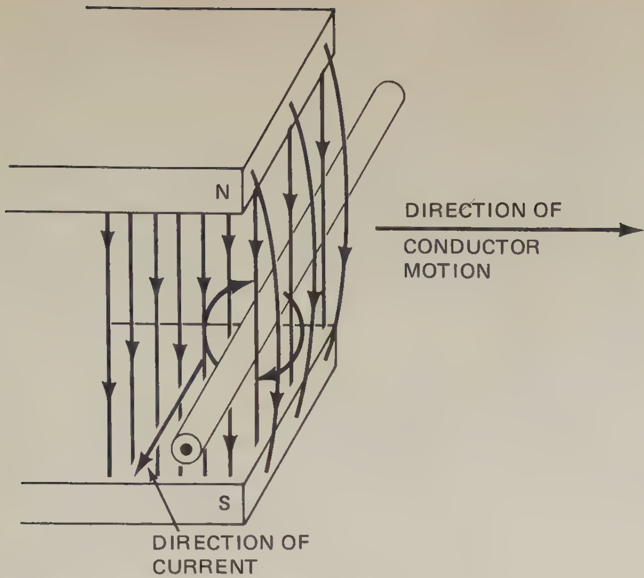


FIG. 27-1 A conductor moving through a magnetic field, as shown, has a flow of current induced in it.

magnetic field. The cutting of the magnetic field forces current to flow in the conductors.

For example, look at Fig. 27-1, which shows a conductor being moved through a magnetic field. Current is being induced in the conductor in the direction shown by the arrow. The dot in the end of the conductor means that the current is moving toward you. If it were moving away from you, there would be a cross in the end of the conductor. In the generator, many conductors are moved through a magnetic field. This produces a strong current. The faster the conductors move and the stronger the magnetic field, the stronger the current. In the generator, the conductors move in a circle throughout the magnetic field.

If two conductors in a magnetic field were moving in opposite directions, the current induced would be in opposite directions. Figure 27-2 shows these two conductors formed into a loop, with the ends connected to two segments of a commutator and with a pair of brushes to take off the current induced or generated in the loop. A light bulb, which is the electrical load, is connected between the brushes.

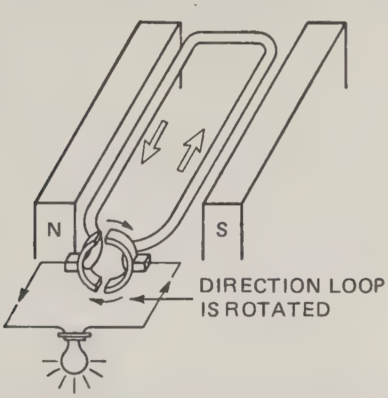


FIG. 27-2 Simple generator showing direction of induced current.

In Fig. 27-2, the commutator segments are physically attached to the loop. The brushes are stationary so that sliding contact is made between the brushes and the commutator segments. Current produced by the moving conductor will flow through the bulb and cause it to light. When the loop is revolved in a clockwise direction, current will flow around the loop and through the commutator bars, brushes, and lamp. When the loop is rotated 180 degrees, the two sides of the loop change positions but the current induced still goes through the lamp in the same direction. This is because the commutator segments also change positions.

○ 27-4 SMALL-ENGINE STARTER-GENERATORS

Some small engines use a charging system that is part of a combination starter-generator. Figure 27-3 shows a basic wiring diagram of the starter-generator. It cranks the engine for starting and acts as a generator after the engine has started. The combination unit has two fields: a shunt field and a series field. Armature current flows in the series winding. During cranking, both fields work together to develop torque. During operation as a generator, the shunt winding produces the effective field. The series field acts only as a bucking field to prevent excessive output. A variation of this arrangement, shown in Fig. 27-4, includes another terminal so that the motor field or series field can be connected separately to the starting switch. With this arrangement, the series field has no effect during the operation of the unit as a generator. The unit shown in Fig. 27-3 is used with a voltage regulator. The unit in Fig. 27-4 requires a current and a voltage regulator. Figure 27-5 shows the complete wiring system for a starter-generator. The starter-generator cranks the engine to start it. Then, when the engine is running, it produces current that puts back into the battery the current taken out by the starter.

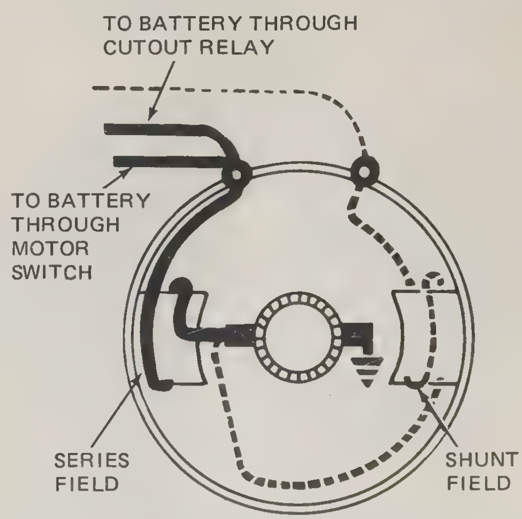


FIG. 27-3 Wiring diagram of a starter-generator. (*Delco-Remy Division of General Motors Corporation*)

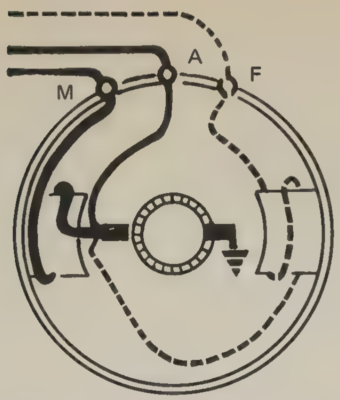


FIG. 27-4 Wiring diagram of a starter-generator with independent generator and motor coils. (*Delco-Remy Division of General Motors Corporation*)

The wiring system shown in Fig. 27-5 includes a voltage regulator. Its purpose is to prevent the generator from producing excessive voltage and current. Excessive voltage could burn out any lights or other electrical devices connected into the circuit. Excessive current would overcharge the battery, shortening its life.

The starter-generator shown in Fig. 27-5 is connected by a belt to the engine for both starting and generating. The starter-generator has two sets of field windings: one for cranking the engine and the other for producing current. When the starter switch is closed, battery current flows through the starter field windings. These windings are made of heavy copper wire so that a heavy current can flow through them. This produces a strong magnetic field, which results in a strong cranking effort. The armature is spun and the crankshaft turns, and so the engine starts.

Then the operator opens the starter circuit by opening the starter switch. This opens the starter field windings, and so starter action is ended. Now, as the engine comes up to speed and drives the starter-generator, the generator begins to produce current. A magnetic field is produced in the generator by the generator field windings, which are made up of relatively light copper wire. These windings are shunted, or connected across, the armature. They use up a small amount of the current that the armature produces. This creates a magnetic field in which the armature spins. The armature windings that have served as starter windings now begin to serve as current producers.

Now let us examine more closely how the armature spinning in the magnetic field produces current and how this current is taken out of the starter-generator. Whenever a wire is moved in a magnetic field, current is produced in the wire. Figure 27-1 illustrates this principle. As the wire moves through the magnetic field, the wire cuts through the lines of force. This action forces electrons in the conductor to move toward you as shown in Fig. 27-1. When the two ends of the conductor are connected to a complete circuit, the electrons (or current) move through the circuit. The stronger the magnetic field and the faster the conductor moves through it, the more current will flow.

Figure 27-6 shows two variations of the starter-generator charging system, one using a starter solenoid. The purpose of the solenoid is to make it possible to locate the starter switch some distance from the battery and starter. This reduced the length of heavy cable needed to complete the circuit between the battery and starter. Only a light wire is needed between the switch and solenoid, because the solenoid needs only a small amount of current to make it work. When the switch is turned to SOLENOID for starting, the solenoid is connected to the battery and a magnetic field is produced. This magnetic field pulls in an iron plunger which forces heavy contacts to close. These heavy contacts connect the battery to the starter, and so the engine is cranked.

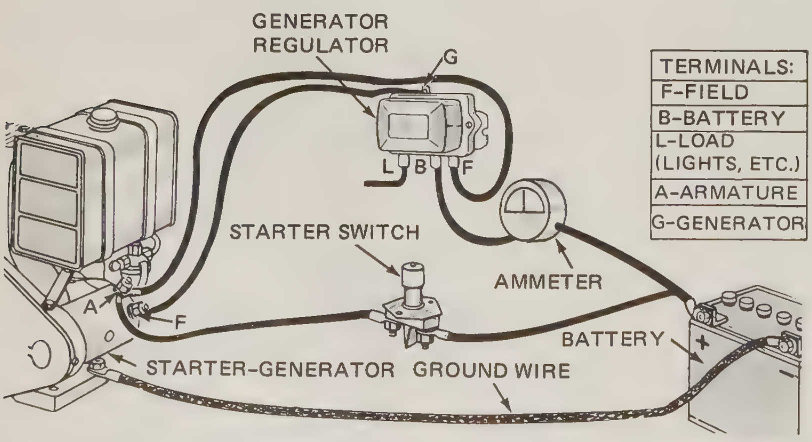


FIG. 27-5 Wiring circuit of a typical starter-generator system. The starter-generator not only starts the engine, but also generates current to charge the battery. The system includes a regulator to control the generator.

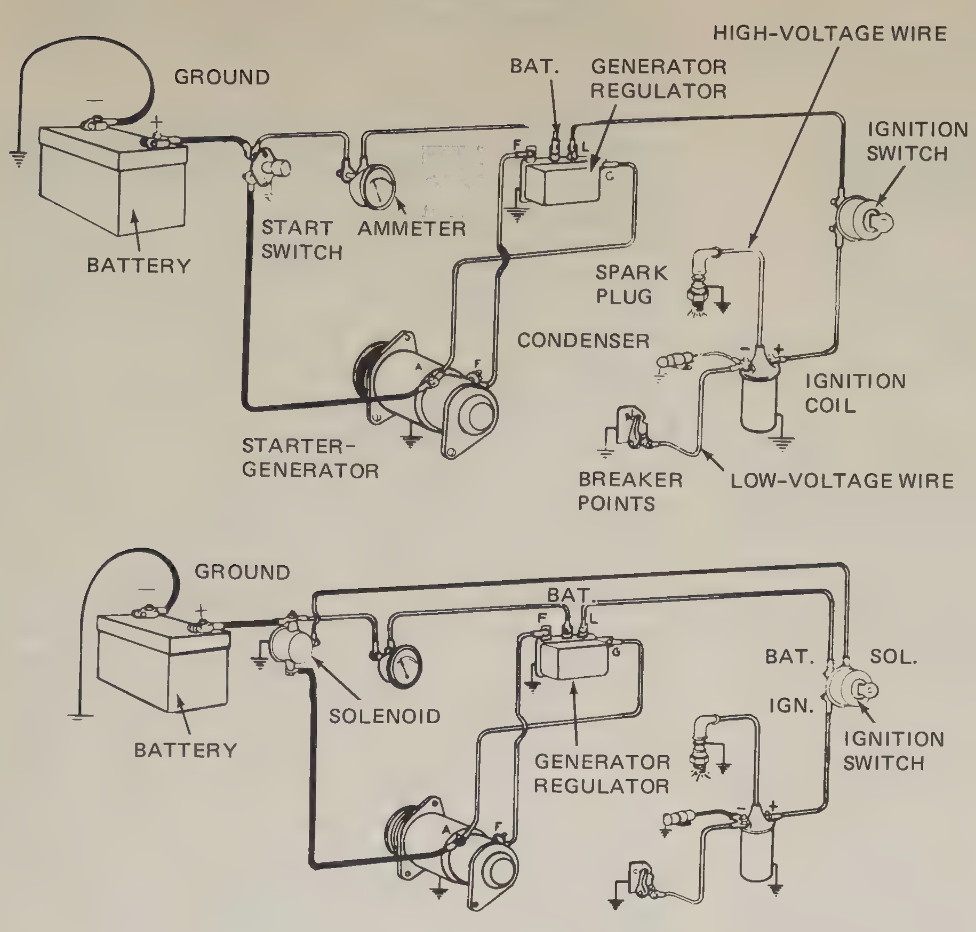


FIG. 27-6 Wiring diagrams of two types of starter-generator systems, one without a solenoid and the other with a solenoid. (*Kohler Company*)

A wiring diagram of a starter-generator charging system is shown in Fig. 27-5. The current, as it comes from the generator, passes through the generator regulator. The functions of this unit are to prevent excessive generator voltage and current and to protect the system from battery discharge through the generator when the engine is not running. There are three separate devices in the generator regulator. These are a cutout relay, a voltage regulator, and a current regulator. These devices are described later in ○ 27-10.

○ 27-5 GENERATOR CONSTRUCTION AND OPERATION

Generators have not been installed in new automobiles for many years. But you will often see generators on small engines and garden tractors. A typical dc generator looks like the one shown in Fig. 27-7. In contrast, the alternator is shorter and bigger around.

The generator has two main parts, the armature and the field-frame assembly, as shown in Fig. 27-8. The field-frame assembly includes the field coils or windings and the field frame. The armature has a large number of conductors in it. The field-frame assembly produces the magnetic field through which the armature conductors move. Therefore, current is induced to flow in the conductors.

Figure 27-9 shows a disassembled generator. Note the appearance of the armature. As the loops or windings in the armature cut through the magnetic field, current is produced. This current flows through the commutator and brushes and passes on to the load, or electrical device being powered.

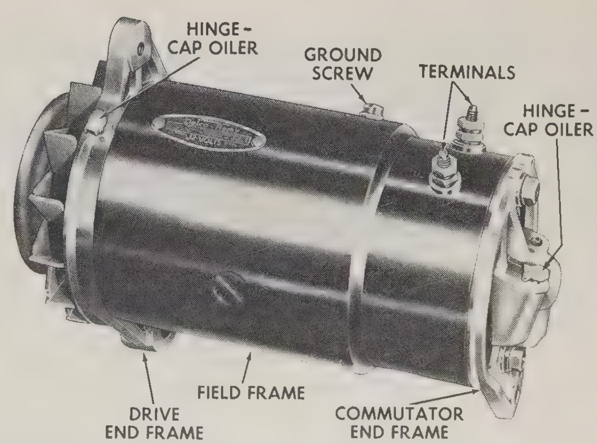


FIG. 27-7 A dc generator. (*Delco-Remy Division of General Motors Corporation*)

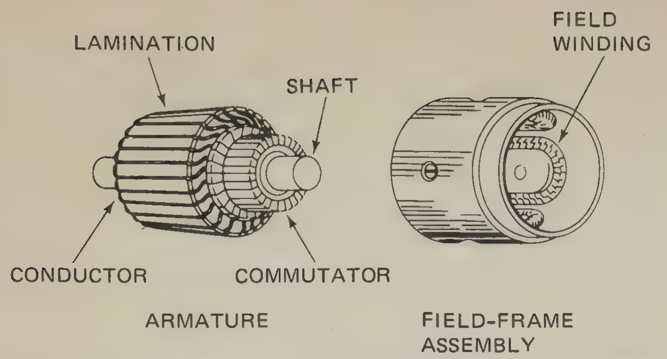


FIG. 27-8 The generator armature and field-frame assembly. (*Delco-Remy Division of General Motors Corporation*)

The fan is attached to the front end of the shaft so that it pulls air through openings in the housing, cooling the wiring and other internal parts. This is necessary because the generator runs continuously. In doing so, it gets hot. Without adequate cooling, it would overheat and burn out.

The dc armature has many loops or coils which rotate in the magnetic field. These loops are connected so that current flows in all the loops.

The amount of current induced in the conductors is based on the number of lines of force that the conductors cut per second. As the armature speed is increased, the conductors cut through more lines of force each second and this induces more current in each conductor. Increasing the strength of the magnetic field (adding lines of force) also produces more current from the generator.

○ 27-6 PRODUCING THE MAGNETIC FIELD The armature conductors must move through a magnetic field so that current will be induced in them. The magnetic field from a permanent magnet could be used in the generator, but the magnetic field and the current would not be very great. No control of the output could be obtained except by varying the generator speed. To obtain a strong magnetic field that can be controlled to regulate generator output, field coils are used. These coils are wound and connected to the generator brushes so that part of the current from the armature flows through them. This causes the field coils to create a powerful electromagnetic field through which the armature must carry the conductors.

When the generator is at rest, no current flows in the generator armature or field winding. However, when the generator is producing current, part of the current flows through the field winding and creates a strong magnetic field.

Initially, there is only a small amount of magnetism in the field pole shoes. This small amount of magnetism is called the residual magnetism, because it is the residue of magnetism remaining after current stops flowing. However, this is enough to induce some voltage in the armature windings as they start to rotate. This armature voltage causes some current flow through the generator field windings to reinforce the residual magnetism and produce a stronger magnetic field. The stronger field permits the generator to produce an even higher voltage, which increases the field current. This process of the output's reinforcing the field magnetism (which then increases the voltage) continues until the generator reaches its maximum output voltage, as determined by the armature speed and the resistance of the field winding. The period of time required for the voltage

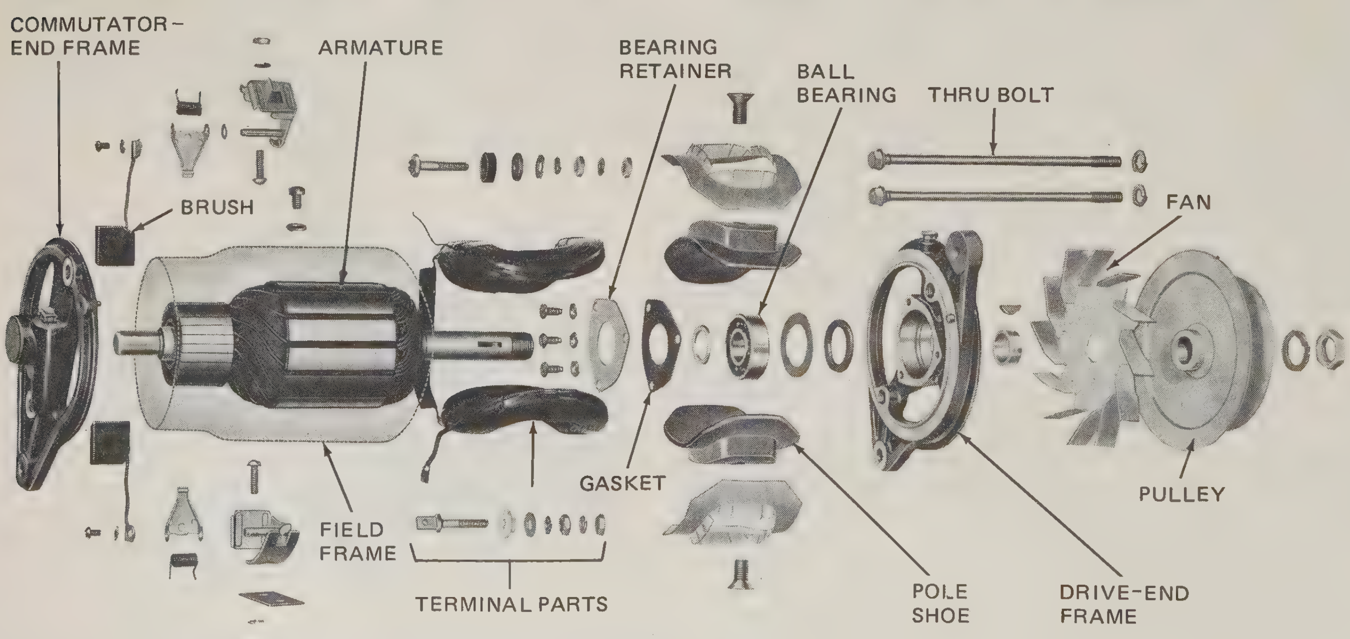


FIG. 27-9 Disassembled view of a typical dc generator. (*Delco-Remy Division of General Motors Corporation*)

to reach maximum is called the buildup time. In low-output generators, such as those used with small engines, the buildup time is very short.

○ 27-7 DRIVING THE GENERATOR

The generator is usually driven by a V-belt from a pulley on the engine crankshaft. Figure 23-31 shows one arrangement for a starter-generator. These units are described in ○ 23-21. On many liquid-cooled engines, such as those used in automobiles, the belt also drives the water pump and fan (Fig. 19-6).

○ 27-8 GENERATOR REGULATORS

Generators require regulation. Regulation is achieved by controlling the amount of current flowing in the generator field windings. Regulation means preventing the generator from producing excessive voltage and current. Without regulation, a generator would continue to increase its output as its speed increases. Eventually, the generator would be producing so much current that it would overheat and burn up. It is all right for the conductors in an electric toaster to get red hot. But if the conductors in a generator become red hot, the generator will be badly damaged or ruined.

As generator armature speed increases, the generator produces increasing voltage and more current. This is because the conductors are cutting more lines of force per second. The increased voltage not only sends more current to the load, but also sends more current through the generator field windings. This, in turn, causes the magnetic field to become stronger. The stronger magnetic field, providing more lines of force, further increases the number of lines of force that the conductors cut per second. This sends the voltage still higher, and again there is a further increase in generator output and field current. The voltage and current would continue to rise with increasing generator speed until so much current would be produced that the resulting heat would destroy the generator. In addition, if the generator were connected into a charging system, the battery would be badly overcharged. The electrical devices turned on would be damaged or ruined. Consequently, some means of limiting the generator voltage and output must be used so that overheating of the generator and damage to the electrical equipment will not occur.

In all charging systems, a regulating device is used to limit or regulate generator output so that the generator will not damage itself or other components of the electrical system. The regulating device usually connects a resistance into the generator field circuit. This cuts down the field current and weakens the magnetic field. As a result, any further rise in generator voltage and current output is prevented.

○ 27-9 THIRD-BRUSH GENERATORS

Before we continue with our discussion of generator regulators, let us look at a generator used for many years which is self-limiting and needs no external regulator. This is the third-brush generator. In this generator, the field windings are fed from a third brush (Fig. 27-10). In this position, the brush cannot pick up full armature voltage. The two main brushes, A and B, are placed to take off full armature voltage. The field windings being fed from the third brush do not get full armature voltage. However, they get enough voltage to provide them with sufficient current to do their job of producing a good magnetic field. Third-brush generators are used on some farm tractors and small-engine installations.

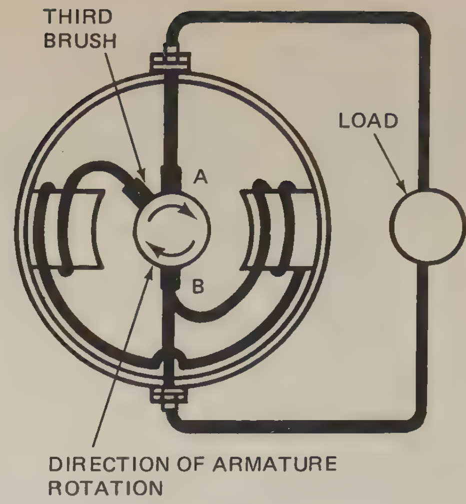


FIG. 27-10 Wiring circuit of a third-brush generator.

As generator output goes up, the magnetic field of the armature causes a shift of the total magnetic field. In effect, the magnetic field shifts past the third brush. The voltage at the third brush is reduced. This reduces the strength of the magnetic field from the field windings. Then the generator output cannot increase further. Therefore, the generator is self-limiting. It cannot increase its output beyond a safe maximum. In many third-brush generators, the third brush can be adjusted to change the maximum output.

Shifting the third brush toward the adjacent main brush (in the direction of armature rotation) will increase maximum generator output. In adjusting these generators, be careful not to set the third brush ahead so much that the generator exceeds its safe maximum rated output.

○ 27-10 THE UNITS IN GENERATOR REGULATORS

Most generators have only two brushes. They are not self-limiting. Without some form of external regulation, their output will go up as speed increases until they overheat and burn up. The most common regulator used with generators has contact points in parallel with a resistance (Fig. 27-11). When the current or voltage starts to go too high, the points open. This puts the resistance in series with the field windings,

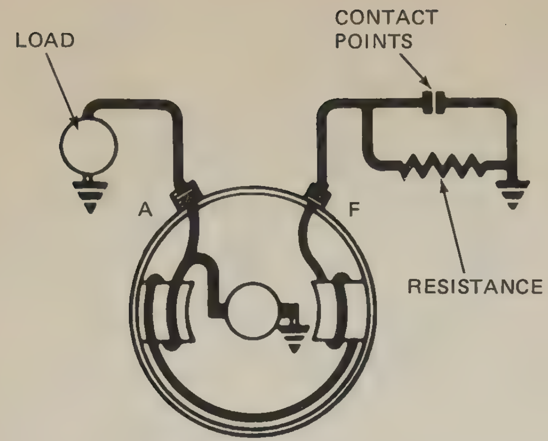


FIG. 27-11 Simplified wiring diagram for a dc generator with an externally grounded field circuit. (*Delco-Remy Division of General Motors Corporation*)

thereby cutting down the field current and magnetism. The output is reduced. The typical regulator used with generators has three units (Fig. 27-12). Here is the way they work:

1. *Cutout Relay.* The cutout relay closes the circuit to the battery when the generator is running. This allows the generator to charge the battery. The cutout relay opens the circuit when the generator stops. This prevents the battery from discharging back through the generator.

2. *Current Regulator.* The current regulator uses a pair of contact points and a resistance. When the generator current output goes to high, the generator load approaches the danger point. The contact points open. When the contact points open, the resistance goes into the generator field circuit and reduces the current. Actually, the points vibrate—open and close—hundreds of times a second. This keeps the resistance in the field circuit just the right amount of time to prevent the output of too much generator current.

3. *Voltage Regulator.* The voltage regulator works on voltage. Voltage is electric pressure. The higher the pressure, or voltage, the more current it pushes through electrical equipment.

   When a battery is low, it will accept a lot of current. But when a battery is fully charged, it will take only a very small current. The small current requires a high pressure, or voltage. Therefore, when the generator is working against a fully charged battery, it keeps pushing its voltage up and up to get current through the battery.

If this voltage were allowed to increase, the battery would be overcharged and therefore ruined. At the same time, all the electrical equipment would have too much current pushed through it by the high voltage. Excessively high current could ruin the electrical equipment. For example, high voltage will burn out the lights.

To guard against excessively high generator voltage, the voltage regulator has a pair of contact points and a resistance. When the voltage gets too high, the

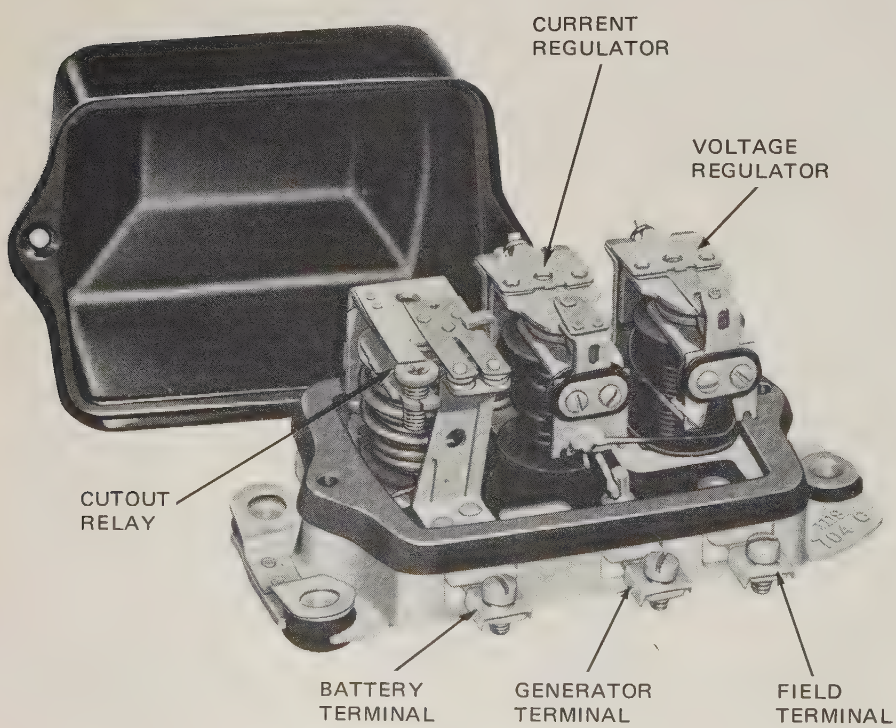


Fig. 27-12 Current and voltage regulator for a dc generator, with the cover removed. (*Delco-Remy Division of General Motors Corporation*)

points open. The resistance goes into the generator field circuit. The magnetic field is weakened, and the generator voltage is held to a safe amount. Actually, the points vibrate, just as in the current regulator. This keeps the resistance in the field circuit just the right amount of time to prevent the generator voltage from going too high.

4. *Combined Actions.* The current regulator prevents the generator from exceeding its rated output. For example, if the generator is rated at 40 amperes, the current regulator keeps the output from going above this amount. The voltage regulator prevents too much voltage. When it operates, it cuts down the generator output to suit the requirements of the battery and the connected electric load. For example, suppose the battery is charged and nothing is turned on but the ignition. In this case the voltage regulator will cut output down to a few amperes. In the three-unit generator regulator, either the current regulator is working, holding output to a safe maximum, or the voltage regulator is working, holding the voltage down and thereby cutting output down. They do not both work at the same time.

○ 27-11 GENERATORS COMPARED WITH ALTERNATORS

In the generator, conductors are moved so that they cut through a magnetic field. This produces current in the conductors. The current is alternating. It flows in one direction through a loop, and then, when the loop moves half a complete turn, the current flows in the opposite direction in the loop. The commutator and brushes change this alternating current (ac) to direct current (dc).

In the ac generator (called the *alternator*), the conductors are stationary and a magnetic field is moved through them. Alternating current is induced in the conductors as the north and south poles of the magnetic field move past them. However, since the alternator has no commutator to change the ac to dc, some other type of rectifier is required. In most alternator charging systems, this is done with electric valves called diodes.

To summarize, the generator moves conductors through a stationary magnetic field and uses a commutator to change the ac to dc. The alternator moves a magnetic field through stationary conductors and uses diodes to change the ac to dc.

○ 27-12 ALTERNATOR PRINCIPLES

Let us look at a simple alternator which will show the alternator principle. In the simple one-loop alternator shown in Fig. 27-13, the rotating bar magnet supplies the moving magnetic field. At the top, the north pole of the bar magnet passes the upper leg of the loop and the south pole passes the lower leg of the loop. Current

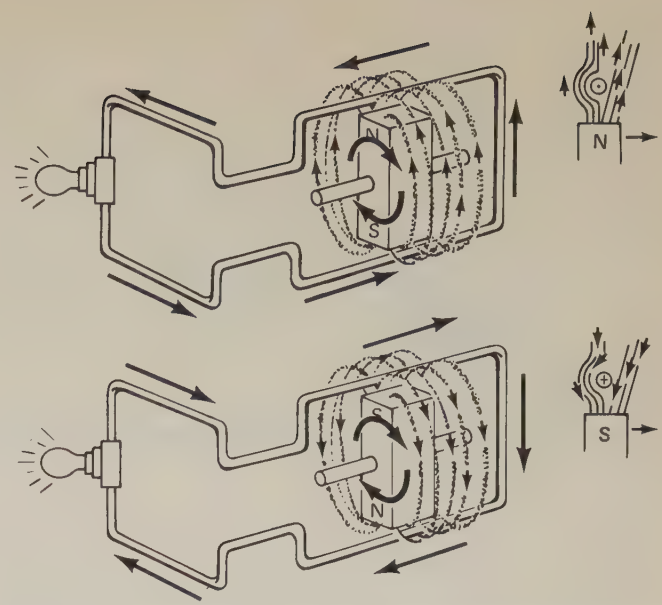


FIG. 27-13 Simplified alternator consisting of a single stationary loop or wire and a rotating bar magnet. The distortion of moving lines of force around a leg of the loop (conductor) and the direction of current (electron) flow are shown at right.

(electron flow) is induced in the loop in the direction shown by the arrows. At the bottom, the magnet has rotated half a turn. Its south pole is now passing the upper leg of the loop, and its north pole is passing the lower leg. Now magnetic lines of force are being cut in the opposite direction by the two legs of the loop. So current (electron flow) is induced in the loop in the opposite direction. As the magnet spins and the two poles alternately pass the two legs of the loop, electrons in the loop are pushed first in one direction and then in the other. Alternating current flows.

Three things will increase the current moving in the loop. These are increasing the strength of the magnetic field, increasing the speed with which the magnetic field rotates, and increasing the number of loops, or conductors, cutting the magnetic field.

On some small engines, motorcycles, and automobiles, the alternator is a separate unit. It is mounted on the engine and driven by a belt. The type of alternator used in many small engines is built-in. Usually, it is combined with the flywheel magneto and uses the same magnets. This type of alternator is called a flywheel alternator. The magneto is a part of the ignition system used on many small engines and motorcycle engines. We described magneto ignition systems in an earlier chapter (Chap. 25).

○ 27-13 FLYWHEEL ALTERNATOR

Let us review briefly how the small-engine magneto works. The flywheel has a series of magnets which are whirled past windings in the stator, or stationary part of the magneto. This produces voltage and current flow from the stator windings. The current flows through a

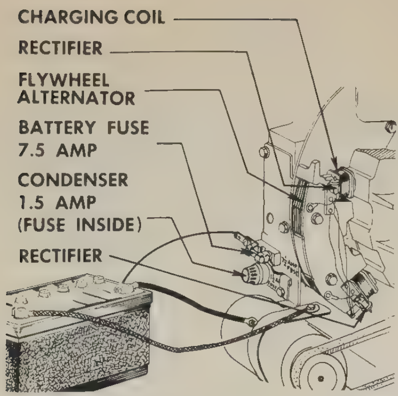


FIG. 27-14 An electric starter system using a battery-powered starter and an alternator mounted on the engine under the flywheel to charge the battery.

set of contacts and the primary winding of the coil. When the contact points are separated, the current stops flowing and the magnetic field in the coil collapses. This collapse produces the high voltage in the coil secondary which fires the spark plug.

The alternator operates on a similar principle and can use the flywheel and the same stator assembly as the magneto. But the stator assembly has different coils for the magneto and the alternator. Figure 27-14 shows a typical installation. The engine has been partly cut away in the illustration to reveal the alternator coils and rectifiers. Figure 27-15 shows how the flywheel alternator works. The magnet ring mounted on the flywheel is made up of permanent magnets. When the magnets spin past the coils on the stator, they produce a constantly changing magnetic field in the cores on which the stator windings are assembled. This means that the magnetic field is constantly moving through the windings. Therefore, current is being induced in the windings. The current induced is alternating, just like the magnetic field. Since ac cannot be used to charge a battery, it must be changed to dc, which flows in one direction only. The device which produces this action is called a rectifier. The rectifier uses several diodes, which are electronic devices that will allow current to flow through them in one direction only.

○ 27-14 RECTIFYING AC

The ac from the alternator must be rectified, or changed to dc. Since ac cannot be used by the battery or other electrical devices, diodes are used to rectify it. The diode is a one-way electric valve for electric current. It allows current to flow through in one direction but not in the other. See Fig. 25-17. Figure 27-16 shows how four diodes can be used to rectify ac. The four diodes are numbered 1 to 4 in the illustration. Look at the top drawing in Fig. 27-16. The current from the stator primary winding follows the conductors, shown solid. Diodes 2 and 4 allow the current to flow through. But diodes 1 and 3 do not, since the current is flowing in the wrong direction for them. However, when the direction of the current reverses, as shown in the bottom drawing, then diodes 2 and 3 will pass the current, but diodes 2 and 4 will not. Therefore, the current can flow in only one direction as it passes through the set of diodes that make up the bridge rectifier.

○ 27-15 THREE-PHASE AC

The circuit shown in Fig. 27-16 is called a single-phase circuit because there is only a single ac source. Such a source would result in a pulsating current. This is characteristic of a single-cylinder engine. It does not provide a smooth flow of power, but rather a series of peaks between

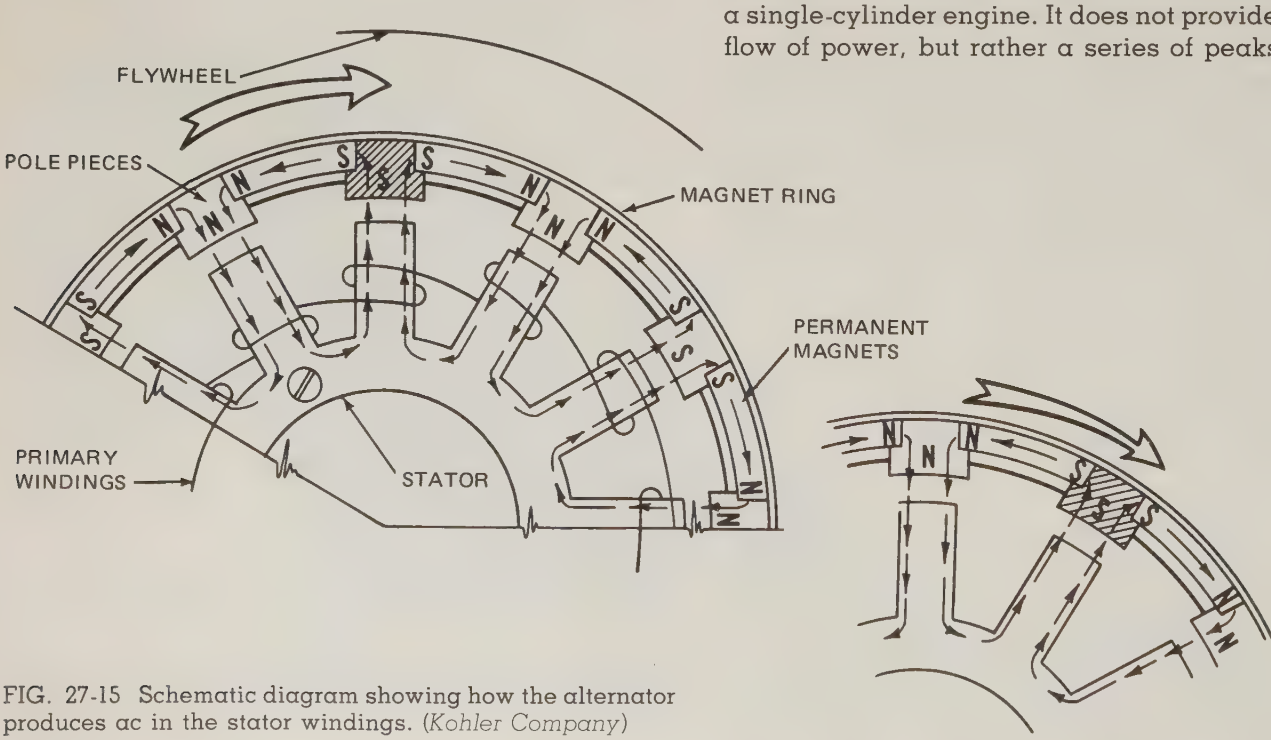


FIG. 27-15 Schematic diagram showing how the alternator produces ac in the stator windings. (*Kohler Company*)

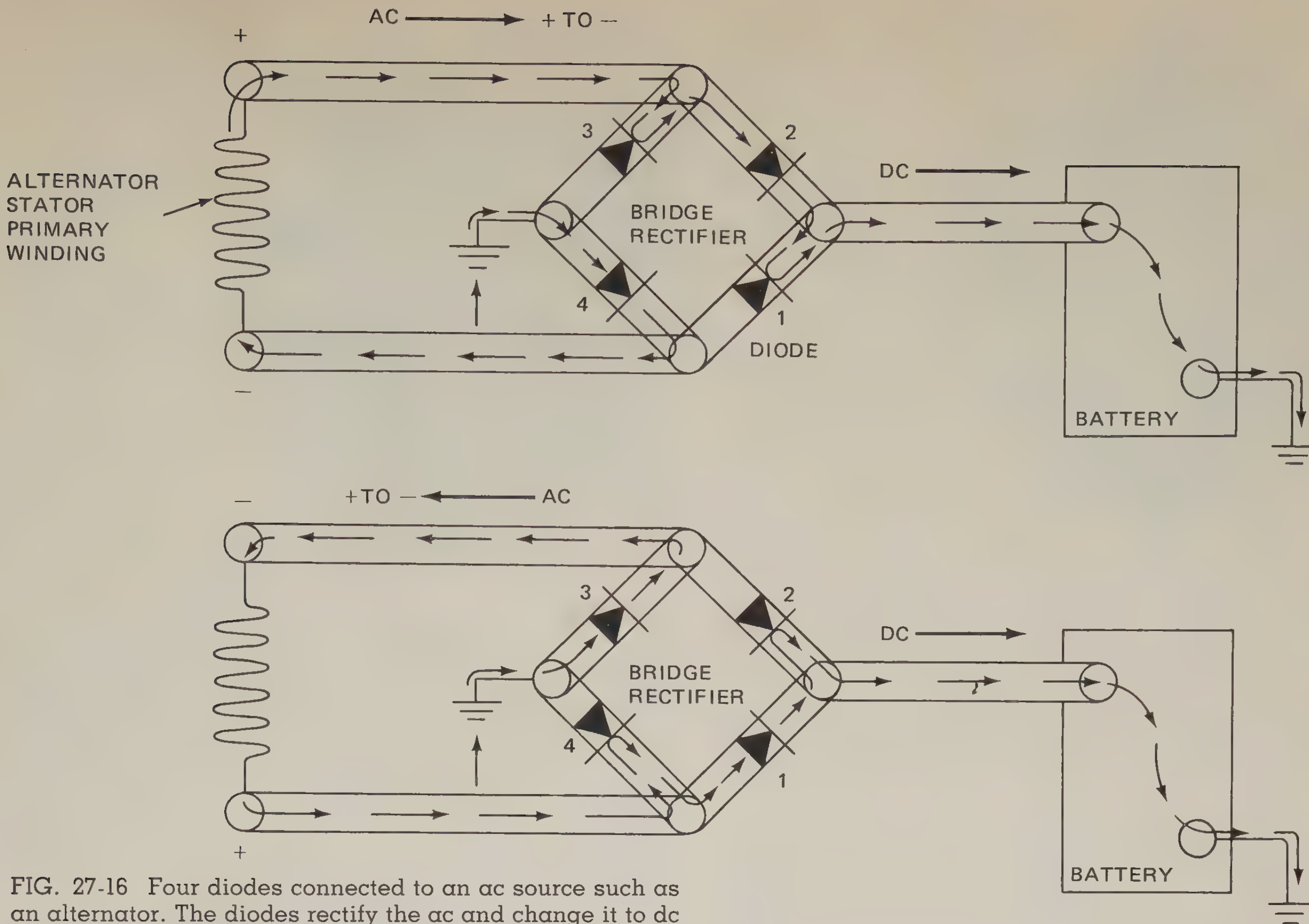


FIG. 27-16 Four diodes connected to an ac source such as an alternator. The diodes rectify the ac and change it to dc to charge the battery. (*Kohler Company*)

which no power is delivered. To provide a smoother flow of current, alternators are wired with more than one winding in the stator so that they deliver overlapping pulses of ac. A typical example is the alternator used on some small engines and motorcycles and on all automobiles. This type of alternator has three stator circuits, interconnected as shown in Fig. 27-17. The ac produced in the three circuits is rectified by the six-diode rectifier.

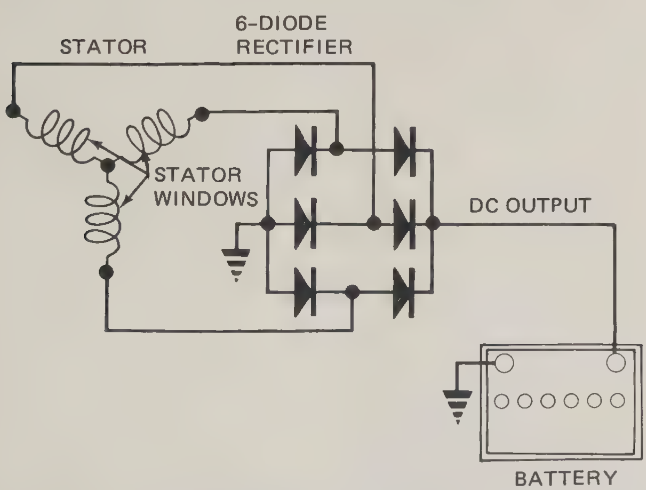


FIG. 27-17 Wiring diagram for an alternator with a six-diode rectifier and a Y-connected stator.

○ 27-16 DIODE HEAT SINKS Diodes are sometimes mounted in the slip-ring end of the alternator, in a metal bracket called a heat sink. The heat sink takes heat from the diodes, which can become rather hot in operation. The heat sink has large fined surfaces. They transfer the heat into the air surrounding the alternator. This keeps the diodes from overheating.

○ 27-17 TYPES OF ALTERNATORS In addition to the flywheel alternator, several types of alternators are in use. Figure 27-18 shows an alternator of the

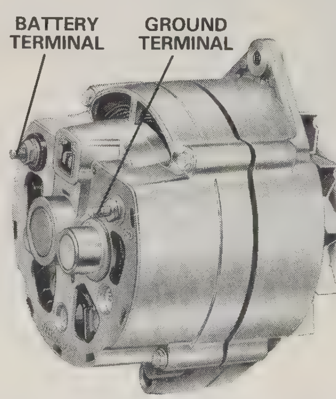
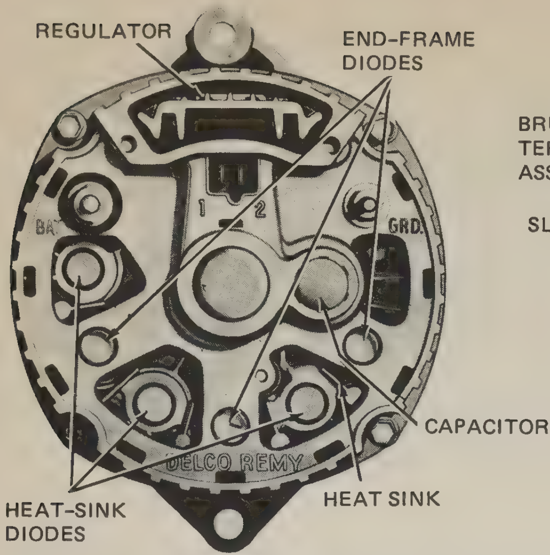


FIG. 27-18 External view of an alternator. (*Delco-Remy Division of General Motors Corporation*)



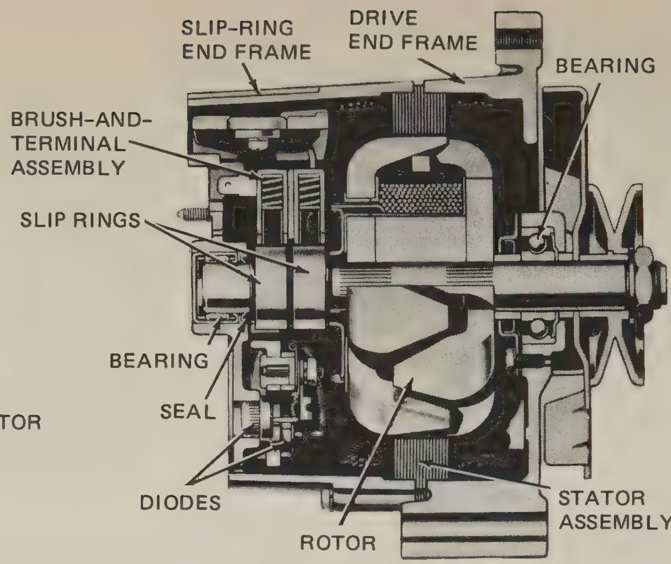


FIG. 27-19 End and sectional views of an alternator with integral diodes and an integral solid-state voltage regulator. (*Delco-Remy Division of General Motors Corporation*)

type that requires a separate external regulator. Figure 27-19 shows an alternator with built-in voltage regulator.

○ 27-18 ALTERNATOR REGULATORS A variety of devices have been used to regulate alternators. When alternators were first introduced, many of the regulators were very complex. They included a field relay, an indicator-light relay, and a voltage regulator. Now alternator-regulator systems have been simplified. Figure 27-20 shows one type of voltage regulator used with alternators. The latest types have the regulator built into the alternator, so that the circuit looks like that shown in Fig. 27-21.

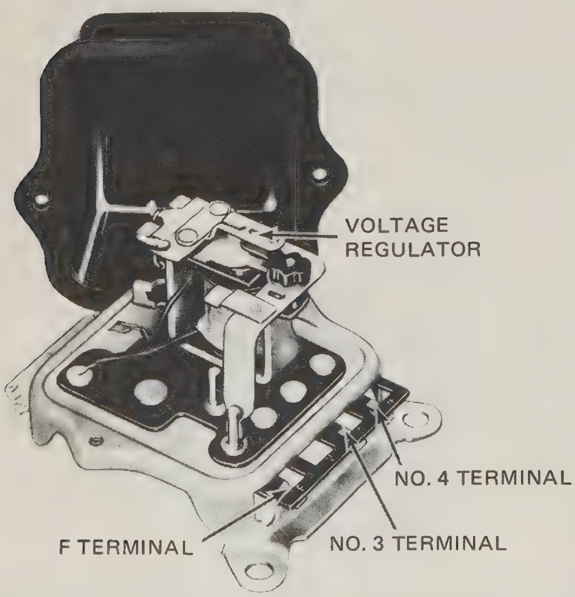


FIG. 27-20 An ac voltage regulator with the cover removed. (*Delco-Remy Division of General Motors Corporation*)

Basically, the regulator limits the alternator field current as necessary to prevent excess alternator voltage. The stator remains permanently connected to the battery. The diodes prevent the battery from discharging back through the stator when the alternator is not operating. The field (rotor) is connected to the battery only when the alternator is operating. The connection is made through either the field relay or the ignition switch.

○ 27-19 REGULATING THE FLYWHEEL ALTERNATOR Figure 27-22 shows the regulating system that one manufacturer uses with the flywheel alternator. In this system, the alternator output is controlled by the actions of four electric devices. These devices, shown in Fig. 27-22, are a zener diode, an SCR (silicon-controlled rectifier), a regulator winding in the stator, and a variable resistor. Except for the zener diodes, these devices have been discussed in earlier chapters.

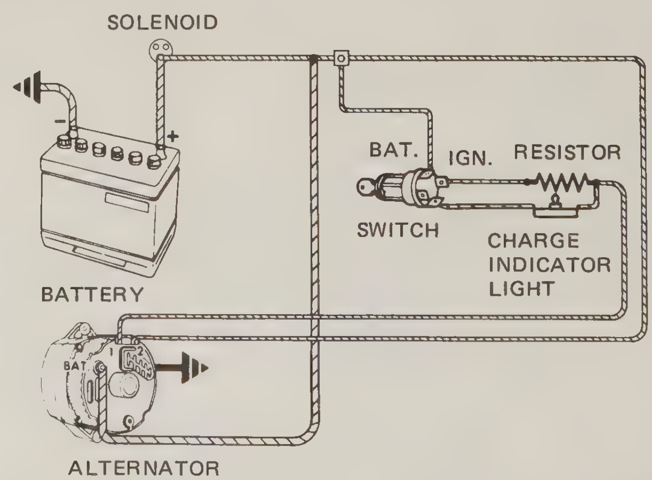


FIG. 27-21 Wiring diagram for a charging system using an alternator with an integral voltage regulator and a charge-indicator light. (*Delco-Remy Division of General Motors Corporation*)

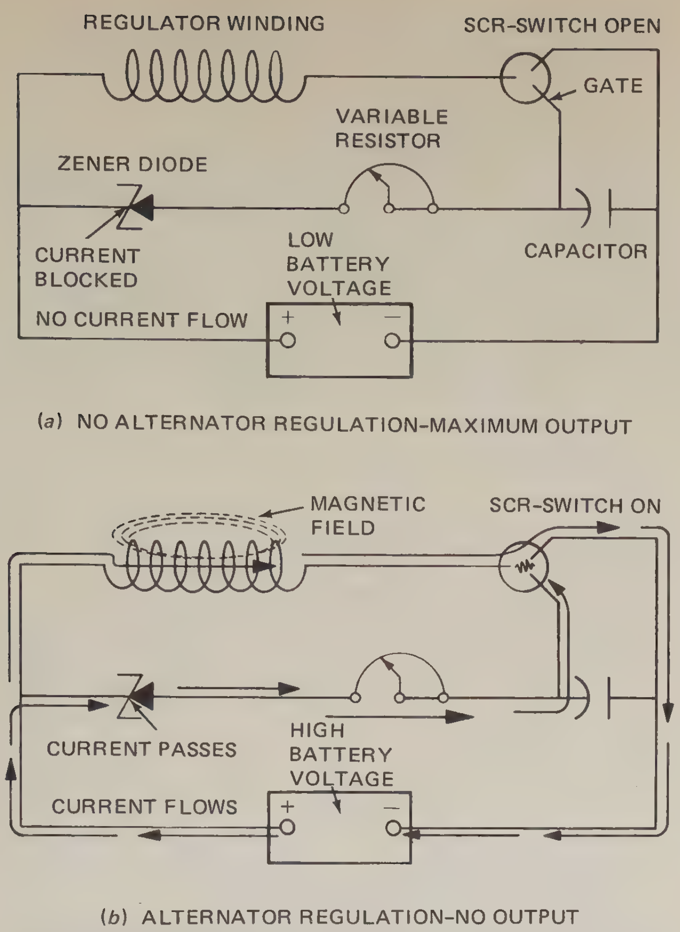


FIG. 27-22 Operation of the regulator for a flywheel alternator. (*Kohler Company*)

A zener diode is a special type of diode that will conduct current in its normally blocked (or reverse) direction under certain conditions. When the voltage across the zener diode is below a certain level that is designed into it, the zener diode will not conduct current in the reverse direction. Under this condition, shown in Fig. 27-22*a*, the zener diode acts like the conventional type of diode that we discussed in ○ 25-8. However, as soon as the voltage increases above a certain level, the zener diode suddenly begins to conduct current in reverse, as shown in Fig. 27-22*b*. This characteristic makes the zener diode very useful in various types of control circuits, such as alternator-regulator circuits.

Now here is how the system shown in Fig. 27-22 controls alternator output: In operation, you can think of the zener diode as the voltage regulator, the SCR as the switch or contact points, and the variable resistor as the adjustable contact-point return spring.

The solid-state devices are assembled into the rectifier-regulator (or simply regulator) as shown in Fig. 27-23. It controls the alternator output by using the zener diode to sense the battery voltage. Then, according to the battery voltage, the regulator acts to increase or decrease alternator output if necessary. This system differs from the other regulators discussed earlier in this chapter. They use current and voltage regulators to measure the generator output and then change it as necessary.

In the system shown in Fig. 27-22*a*, when the battery voltage is low, there is no regulation of alternator output. The alternator produces its maximum output, and this current is used to charge the battery. As shown in Fig. 27-22*a*, the zener diode prevents any current from passing through it and entering the regulating circuit. However, as the battery charges, its voltage increases. When the battery voltage gets high enough, the zener diode reaches its "breakdown" point. When this happens, current suddenly passes through the zener diode, as shown in Fig. 27-22*b*. Current flows through the zener diode to the variable resistor and into the capacitor. This voltage also is applied to the gate of the SCR. The SCR switches on electronically, and current flows through it.

With the SCR on, current now flows through the regulator winding and a magnetic field builds up around it, as shown in Fig. 27-22*b*. The strength of this magnetic field acts to control the alternator output. Any increase in current through the regulator winding brings a corresponding decrease in current through the primary winding of the alternator. When a high charging rate is needed, little or no current flows in the regulator winding. When no charging is needed, maximum current will flow in the regulator winding. Then little or no current flows in the primary winding.

By adjusting the variable resistor in the regulator, the charging voltage can be increased or decreased slightly. The voltage adjusting screw can be seen in

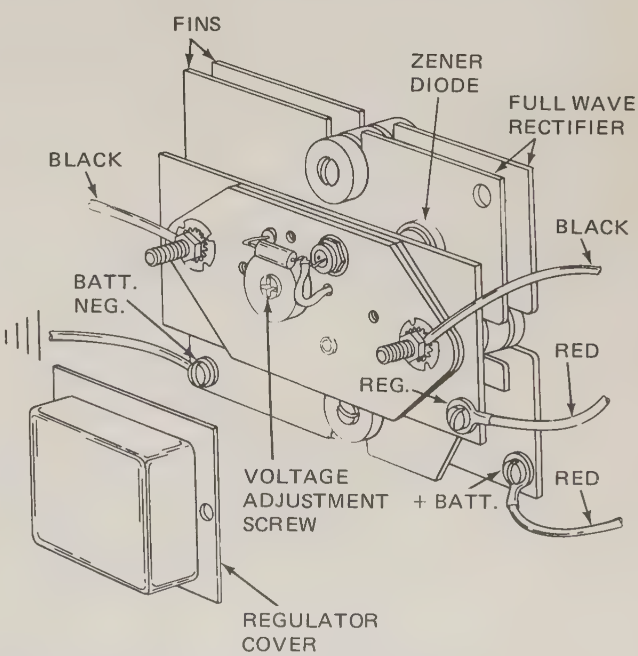


FIG. 27-23 One type of solid-state regulator used to control the flywheel alternator. (*Kohler Company*)

Fig. 27-23, which shows the rectifier-regulator with the cover removed. Notice the fins that are part of the regulator. They are needed because the heat produced by the resistor and zener diode must be carried away. To carry away the heat most effectively, the fins must be mounted in a vertical position. This will provide maximum cooling of the electronic devices in the regulator. Other types of regulators have finned covers.

REVIEW QUESTIONS

1. Name the four characteristics of all charging systems.
2. What is the job of the generator and alternator?
3. In the generator, what job is done by the commutator and brushes?
4. Explain the basic operation of a starter-generator when it operates as a generator.
5. Why would an engine have a starter-generator instead of a separate electric starter and a separate generator?
6. What is the purpose of the generator regulator?
7. What are the two main parts of the generator?
8. Which part of the generator is composed of many loops of wire that are rotated through a magnetic field?
9. What determines the amount of current induced in a rotating conductor?
10. What creates the magnetic field in a generator?
11. How are most generators driven?
12. What is a third-brush generator?
13. Explain how a third-brush generator can be self-limiting.
14. Name the three units in a generator regulator.
15. What is the job of the cutout relay?
16. How does the voltage regulator prevent excessively high voltage?
17. How does the current regulator prevent excessive current output?
18. How many units in the generator regulator operate at the same time?
19. What is the basic difference between a generator and an alternator?
20. What does the alternator use to change the ac to dc?
21. What is the name of the electronic device that permits current to flow through it in only one direction?
22. Describe the operation of the flywheel alternator.
23. Why can't ac be used to charge a battery?
24. What is a three-phase alternator?
25. Why do diodes need to be mounted in a heat sink?

SELF PROJECTS

1. If you are able to get discarded generators and alternators, disassemble them. Examine the internal parts and note how the connections are made to the generator brushes and to the alternator brushes and diodes. See if you can trace the connections between the diodes and the stator of the alternator.
2. Write a short explanation of the differences in design and construction between the generator and alternator. Explain why, in your opinion, many manufacturers have switched to alternators in recent years.
3. Refer to manufacturers' shop manuals and find the wiring diagrams they show for the charging systems on their engines. Copy these diagrams for your notebook. Use colored pencils to show the circuits. For example, you could use a red pencil to show the rotor circuit, then a blue pencil to show the stator and diode circuit.

28 Chapter

Servicing Small-Engine Charging Systems

After studying this chapter, you should be able to:

1. **Discuss how to troubleshoot a dc charging system**
2. **Demonstrate how to polarize a dc generator**
3. **Demonstrate how to test and adjust a generator regulator**
4. **Demonstrate how to rebuild and test a generator**
5. **Explain how to troubleshoot a starter-generator**
6. **List the cautions for alternator service**
7. **Demonstrate how to service the flywheel alternator**

GENERATORS

○ 28-1 TROUBLESHOOTING DC CHARGING SYSTEMS The typical dc charging system consists of a battery, regulator, generator, and connecting wiring, as shown in Fig. 28-1. Normally, the regulator limits the generator output so that it produces enough current at the proper voltage to keep the battery fully charged, while preventing excessive voltage. It also is normal for the charging system to charge at a high rate when the battery is weak or discharged and to reduce the charging rate as the battery becomes charged.

When you receive a complaint about a weak battery or generator trouble, you must make tests to determine if there is trouble, and if there is, whether it is in the battery, generator, regulator, or wiring. A few checks will indicate whether the generator-regulator system is operating normally and what could be causing any abnormal conditions.

The four general charging-system complaints are high charging rate, low charging rate, no ammeter reading, and faulty charge-indicator light operation. In addition to these conditions, a generator may become noisy because of mechanical trouble.

○ 28-2 USING THE TROUBLESHOOTING CHART Table 28-1 (on page 272) is a troubleshooting chart listing the various types of charging-system troubles and their causes and checks or corrections. Each condition and its causes are discussed later.

High Charging Rate The typical engine operator does not know when the generator has too high a charging rate. Instead, the operator usually notices that the ammeter needle does not drop back to near zero, the lights flare up as engine speed is increased, the light bulbs burn out too often, or the battery needs water frequently. All these symptoms are caused by

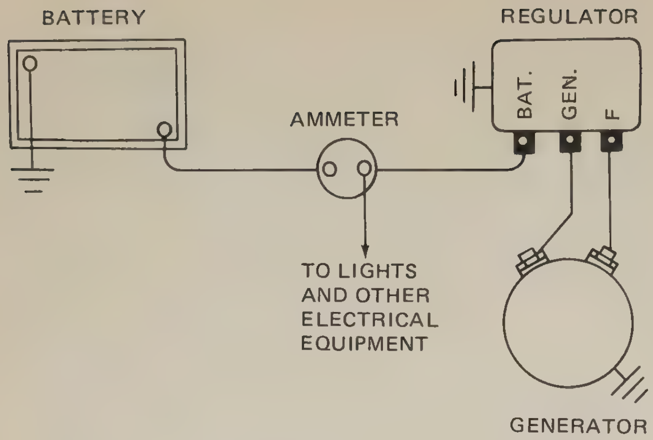


FIG. 28-1 A dc-charging-circuit wiring diagram.

failure of the voltage regulator to keep the generator voltage down to normal values.

As shown in Table 28-1, overcharging can be caused by a defective or misadjusted voltage regulator or a defect in the field circuit of the generator. A battery with one or more bad cells would cause a high charging rate, because it would never become fully charged.

Low Charging Rate A low charging rate will produce a discharged battery or an indication of no charging on the ammeter or charge indicator light. The actual rate of charging can vary from no charging at all to an output which is slightly below the level needed for normal use.

Before you suspect the charging system, check the battery and the battery connections, as covered in Chap. 22. A bad battery connection can limit the charging current and give an indication of a weak battery. A bad battery connection also can reduce the charging rate so that the battery never becomes fully charged.

Table 28-1 shows that a low charging rate may be due to loose connections, a loose generator drive belt, a regulator which has a defective or misadjusted voltage regulator, cutout relay, or current regulator, or a defective generator.

No Ammeter Reading The ammeter is connected in series with the charging circuit as shown in Fig. 28-1. Current entering or leaving the battery flows through the ammeter. If there is current flow and no meter indication, the meter is defective.

There is always a chance that the charging system is not working and so there is no charging current. To check the ammeter in this case, turn on the lights, or other electrical device, with the engine not running and watch the ammeter. It should indicate discharge. If it does, the ammeter is working and you should check the charging system. If the meter does not show discharge, check the ammeter.

Charging Indicator-Light Failure Many engines have an indicator light to show whether or not the generator is charging when the ignition switch is on. There are two potential troubles: The light can fail to

TABLE 28-1 DC GENERATOR-REGULATOR TROUBLESHOOTING CHART

Condition	Possible Cause	Check or Correction
1. High charging rate	a. High voltage-regulator setting	Reduce setting
	b. High temperature	Reduce voltage-regulator setting; reduce battery specific gravity
	c. Defective battery	Replace battery
	d. Generator field windings grounded or shorted	Repair or replace generator
	e. Short, ground, or open in regulator	Repair or replace regulator
2. Low charging rate	a. Defective wires or connections	Replace wires; clean and tighten connections
	b. Low voltage-regulator setting	Adjust or replace regulator
	c. Dirty regulator contact points	Clean and replace points or regulator
	d. Open in regulator	Repair or replace regulator
	e. Defective generator	Repair or replace generator
	f. Cutout relay not closing	Adjust, repair, or replace regulator
	g. Drive belt loose	Tighten or replace if necessary
3. No ammeter reading	a. Ammeter defective	Replace
	b. No generator output	See item 2
4. Charging indicator-light failure	a. Bulb burned out	Replace bulb
	b. Bad connection	Repair connection
	c. No generator output	See item 2
5. Noisy generator	a. Generator mounting loose	Tighten
	b. Pulley or fan loose	Tighten
	c. Worn brushes or bearings	Repair or replace generator

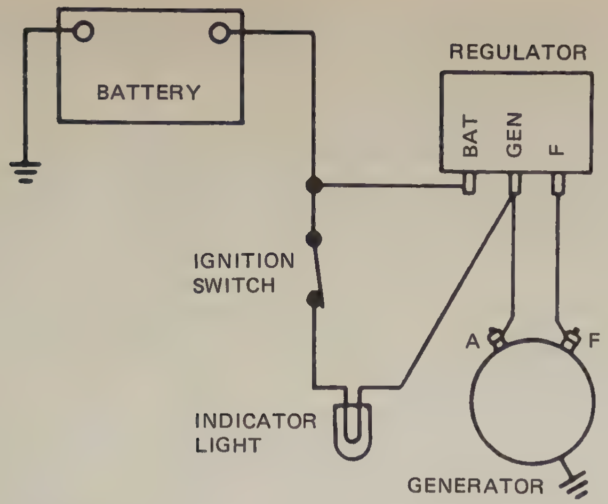


FIG. 28-2 A dc charging circuit which includes a charge indicator light.

glow at all, or it can stay on during charging. Figure 28-2 shows how the indicator light is wired on many engines. If the bulb does not light, there could be a bad bulb or connection. If the bulb stays on when the engine is running at a medium speed, check the charging rate.

○ 28-3 CAUTIONS FOR GENERATOR AND REGULATOR TESTING Certain basic cautions apply to all dc generator-regulator systems. Keep these instructions in mind during any service work on dc charging systems:

1. Be sure the correct regulator is being used. The wrong regulator in a charging system will usually lead to trouble. For example, if a regulator is of the wrong polarity, the current will flow through the regulator contacts in the wrong direction. The contact points will then wear away rapidly, and defective regulator action will result.
2. Never close the cutout relay or circuit-breaker contact points by hand with the regulator connected to the battery. This may damage the contact points. On many regulators, enough current could flow to cause the points to weld together, resulting in damage to the generator and regulator.
3. The regulator must be at operating temperature and in the normal operating position when electrical tests are made. Some manufacturers supply or recommend use of a special thermometer to check the temperature to make sure that it is correct when the electrical settings are checked.
4. Cycle the generator after every voltage adjustment by slowing the engine to idle and then bringing it back to speed before checking the setting. A variable resistance in the generator field circuit will accomplish the same results.
5. Replace the regulator cover after every voltage regulator adjustment, and then check the settings.
6. Make the meter connections according to the markings on the regulator terminals and not according to the wiring circuits shown in this book.
7. Never connect a radio bypass condenser from the field terminal of the generator or regulator to ground. This will burn the regulator contacts.
8. Repolarize the generator after every check or adjustment.
9. Never operate the generator on open circuit, with the circuit to the battery or other electrical units disconnected.

○ 28-4 POLARITY OF DC GENERATORS After any wires have been reconnected to the regulator or the generator, you should repolarize the generator. This is to make sure that the generator has the correct polarity with respect to the battery it is to charge. Reversed polarity may be caused by any disconnecting and reconnecting of wiring. This can produce a momentary reverse flow of current through the field windings. Reversed polarity reverses the residual magnetism in the pole shoes so that the generator voltage builds up backward with respect to the battery. This produces arcing and burning of the cutout-relay points and failure to charge the battery.

Polarizing the generator is easy. On standard Autolite and Delco-Remy dc generators, the generator field winding is grounded externally. The ground is not in the generator, but through the regulator. This type of generator circuit is often called an *A* circuit generator. To polarize it, before starting the engine, momentarily connect a jumper wire from the insulated or positive side of the battery to the armature or *A* terminal of the generator. On some engines, this may more easily be done at the regulator by touching a short jumper wire momentarily between the BAT, or battery, terminal of the regulator and the GEN or armature terminal of the regulator.

Some dc generators have the generator field grounded internally or inside the generator. This type of generator circuit is known as a *B* circuit generator. It is polarized by disconnecting the F, or field, terminal wire from the regulator and momentarily touching the wire to the B, or BAT or battery, terminal of the regulator. Either way, the action permits a flash of current to flow from the battery to the generator field windings. The current flows through the field windings in the right direction to polarize the pole shoes correctly. When the generator begins to operate, volt-

age will build up in the right direction with respect to the battery. You can expect to see a spark when you remove the jumper wire.

Never try to polarize an alternator. The connections for polarizing a dc generator will ruin an alternator.

○ 28-5 TESTING THE DC CHARGING SYSTEM An analysis of the charging system includes testing the generator output current, testing the operation of the voltage and current regulators, and testing the action of the cutout relay. A typical testing procedure is given here. While the procedures vary somewhat among manufacturers, the basic methods are the same. Before performing these tests, check the generator belt for proper tension. Also, if a radio suppressor condenser is used on the generator, be sure the condenser is connected to the armature terminal and not to the field terminal. Operate the engine for 10 to 20 minutes to bring the generator and regulator up to operating temperature. Check the engine temperature, being sure not to let the engine overheat.

○ 28-6 THE GENERATOR CURRENT-OUTPUT TEST For this test, bypass the current regulator and test the generator to see if it can produce its rated current as given in the manufacturer's specifications. A typical test setup is shown in Fig. 28-3. This particular charging system has the generator field circuit grounded through the regulator. If the engine is not equipped with an ammeter, stop the engine and connect a test ammeter as shown in Fig. 28-3. Disconnect the lead from the battery terminal of the regulator and connect the ammeter in series with the terminal and the lead. Disconnect and ground the field terminal lead from the field terminal of the regulator. This bypasses the current regulator in charging systems using an *A* circuit generator.

For *B* circuit generators which have internally grounded fields, bypass the regulator by connecting a jumper lead between the field and armature terminals of the generator.

Start the engine and gradually increase its speed until the ammeter indicates the rated generator output current or until the engine reaches operating speed. While the generator is operating under these conditions, check the brushes to see if there is excessive arcing. If there is, then the brushes or commutator should be serviced. If the generator does not produce its rated output, it should be checked to find the cause of low output.

If the test ammeter reads no output current, determine if the generator or the cutout relay is at fault. To isolate the trouble, connect a voltmeter between the armature or output terminal of the generator and ground. The voltmeter should be capable of reading at least 16 volts (on a 12-volt system). If the voltage is 12 volts or less, the generator probably is defective. A voltage reading of 13 volts or more and no output current usually indicates that the cutout relay in the regulator is not closing properly, because of a defect or misadjustment.

○ 28-7 GENERATOR VOLTAGE TEST A test of the generator voltage will indicate whether the wiring inside the generator is properly insulated. Stop the engine, disconnect the test ammeter (if used), and reconnect the battery lead to the B terminal of the regulator. Then connect a voltmeter, which can read up to 16 volts, between ground and the A terminal of the generator, as shown in Fig. 28-4.

Start the engine and increase the speed until the voltmeter indicates at least 16 volts. This reading should occur with the engine running at, or below, its normal operating speed. Immediately slow the engine to prevent damage to the generator.

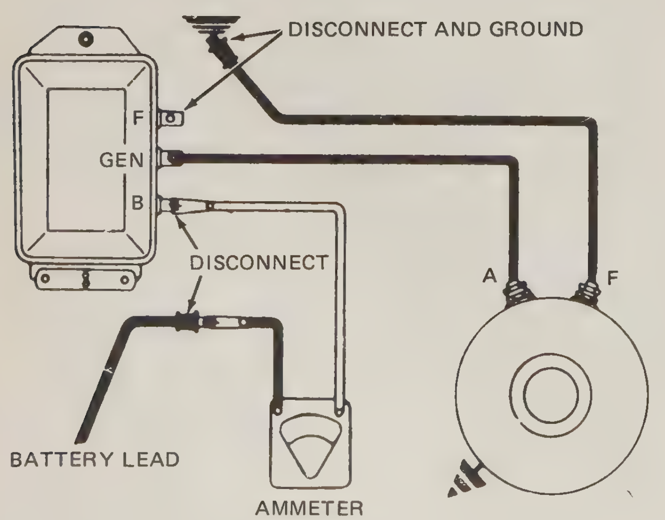


FIG. 28-3 Testing generator current output. (*Delco-Remy Division of General Motors Corporation*)

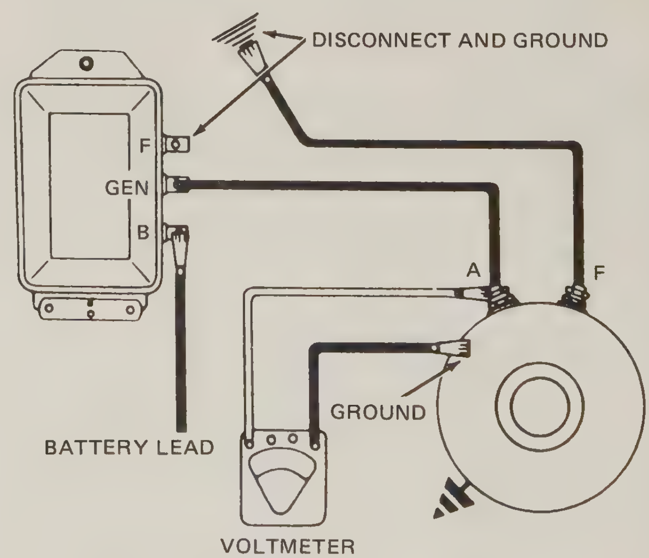


FIG. 28-4 Generator-voltage test. (*Delco-Remy Division of General Motors Corporation*)

If the voltmeter reading does not reach 16 volts, stop the engine and test the battery. The battery should be fully charged. If it is not, substitute a fully charged battery or charge the battery and repeat the test. If you obtain a reading of 16 volts or more, the generator insulation is adequate. If not, there is probably trouble in the generator, regulator, or wiring.

○ 28-8 CUTOUT-RELAY TESTS AND ADJUSTMENTS

The cutout relay in the regulator (which also is called a circuit breaker) should close only when the generator voltage rises high enough to charge the battery. The closing voltage and opening reverse current should be checked whenever the charging system is being tested.

Standard Delco-Remy regulator electrical settings are adjusted by turning a Phillips-head screw. Mechanical settings of air gaps and point openings are adjusted by loosening screws or by bending an armature stop. Details of these adjustments follow. While all settings are checked and adjusted in the same general manner, there are certain important variations in the different models. Always check the manufacturer's specifications before making any check or adjustment of a generator or regulator.

○ 28-9 CLOSING-VOLTAGE TEST

Connect a voltmeter between the GEN terminal of the regulator and ground (Fig. 28-5). There should be no test ammeter in the circuit. An extra ammeter would add undesirable resistance and affect the test result. Slowly increase the generator speed, and note the voltage at which the cutout relay closes on the voltmeter scale. Decrease speed and make sure that the relay points open.

A second method of making a closing-voltage test is to use a variable resistance connected into the generator field circuit (Fig. 28-5). The variable resistor is used to control the current flow through the field coils in the generator. Use a 15-ohm 25-watt variable resistor for 6-volt systems or a 25-ohm 25-watt variable resistor for 12-volt and 24-volt systems.

Adjust the generator field control, or variable resistor, for minimum field current (maximum resistance), and start the engine. Run the engine at operating speed and slowly decrease the field resistance, which increases the field current, until the cutout-relay contact points close. Note the voltage at which the contacts close. It should be between 12.6 and 13.6 volts. Then increase the resistance until the points open.

○ 28-10 CLOSING-VOLTAGE ADJUSTMENT

If the closing voltage is too high, the cutout-relay spring tension is excessive. If the closing voltage is too low, there is too little spring tension. In either case, you will have to adjust the spring tension for the closing voltage specified by the manufacturer.

On many generator regulators, adjust the closing voltage by turning the Phillips-head adjustment screw as shown in Fig. 28-6. Recheck the setting after each adjustment. If the correct setting cannot be made, remove the regulator from the engine for further checks and adjustment.

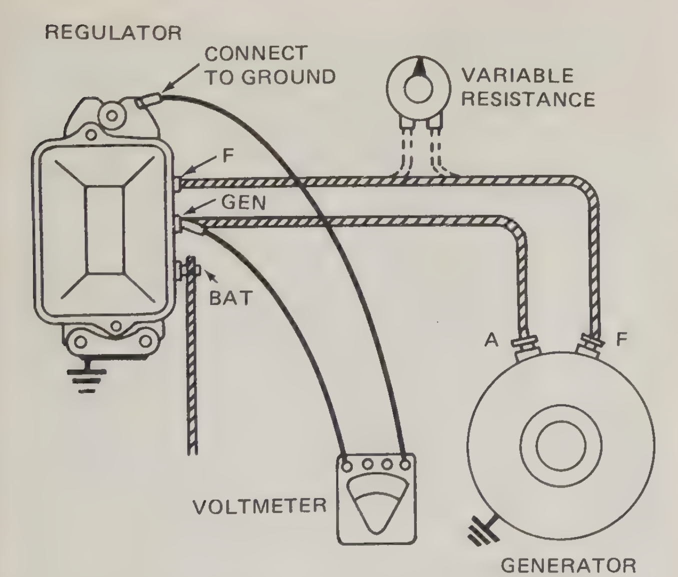


FIG. 28-5 Voltmeter connections to check cutout-relay closing voltage. Variable resistance may be connected in the field circuit, as shown, to cycle the generator or to control generator output. (*Delco-Remy Division of General Motors Corporation*)

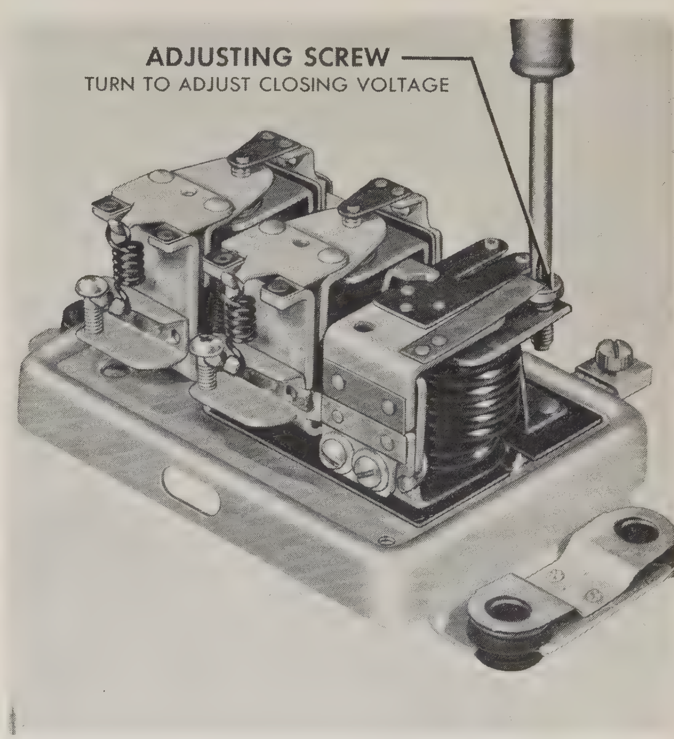


FIG. 28-6 Cutout-relay closing-voltage adjustment on the type with a Phillips-head adjustment screw. (*Delco-Remy Division of General Motors Corporation*)

○ 28-11 OPENING-CURRENT TEST Whenever the generator output voltage falls below the battery voltage, the battery discharges into the generator. This reverse (battery-to-generator) current should cause the cutout-relay contacts to open. The opening-current test is a check of the amount of reverse current required to open the cutout relay. Disconnect the lead from the battery terminal of the regulator and connect a test ammeter in series with this connection, as shown in Fig. 28-3. (You may still have the generator field control and voltmeter connected as shown in Fig. 28-5.)

Turn the generator field control to the maximum resistance position and start the engine. Increase the engine speed. Rotate the generator field control to obtain an output current reading of about one-quarter of the rated current. Slowly increase the field resistance to thereby decrease the field current while observing the output current of the test ammeter. Note how far the ammeter pointer will move below zero before the relay opens and causes the pointer to return to zero. The maximum negative reading is the amount of reverse current required to open the relay contacts. The value can usually be estimated from the meter indication with reasonable accuracy. Check the specifications. If the reverse current is incorrect, remove the regulator and adjust the air gap of the cutout relay.

○ 28-12 VOLTAGE-REGULATOR TESTS AND ADJUSTMENTS The voltage regulator should be checked to see that it maintains the proper generator voltage under varying load conditions. The voltage required to properly charge a battery varies with temperature. The typical voltage regulator is temperature-compensated so that the regulator reduces the charging voltage as the operating temperature goes higher.

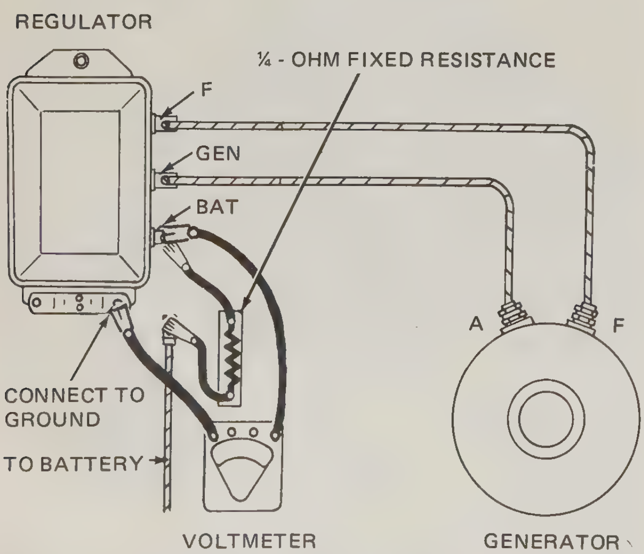


FIG. 28-7 Voltmeter and fixed-resistance connections to check voltage-regulator setting. (*Delco-Remy Division of General Motors Corporation*)

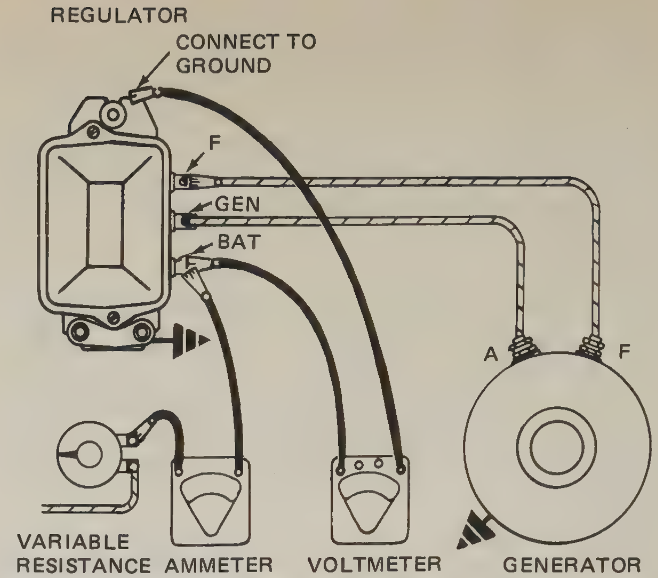


FIG. 28-8 Voltmeter, ammeter, and variable-resistance connections for checking voltage-regulator setting by the variable-resistance method. (*Delco-Remy Division of General Motors Corporation*)

Two different methods of checking the voltage-regulator setting can be used, according to the type of regulator. For all regulators except the double-contact type, either a fixed or a variable resistance connected into the charging circuit is used. With the fixed-resistance method, the resistance and the voltmeter are connected as shown in Fig. 28-7. Run the engine for 15 minutes. Then cycle the generator by slowing it until the voltage drops to one-quarter of the rated value. Then increase generator speed and note the voltage rating.

With the variable-resistance method, connect the variable resistor, ammeter, and voltmeter as shown in Fig. 28-8. Operate the engine for 15 minutes with the variable resistor adjusted to allow a generator output of not more than 10 amps. Then cycle the generator as described above. Note the voltmeter reading.

Connections for double-contact regulators are the same as shown in Fig. 28-7 except that a variable resistor is connected into the generator field circuit. This resistance is used to control and cycle the generator (Fig. 28-5). With the variable resistor turned to minimum resistance, operate the generator at medium speed so that the regulator will operate on the upper contacts. Run the engine for 15 minutes with the regulator cover in place. Cycle the generator by turning the variable resistor first to the open or maximum-resistance position. Then turn the resistor to the closed or minimum-resistance position again. Check the voltage with the voltage regulator operating on its upper contacts. Note the voltage. Increase the resistance slowly until the voltage regulator begins

to operate on the lower contacts. Note the voltage. The lower contacts should operate at 0.1 to 0.3 volts lower than the upper contacts.

All Delco-Remy voltage regulators, except for the double-contact regulators, are adjusted by turning an adjusting screw (Fig. 28-9). Turn the adjusting screw clockwise to increase the voltage and counterclockwise to lower the voltage. Always make the final adjustment by increasing, not lowering, the screw setting. Reduce the setting slightly below the specified value, and then bring it back up to the specification.

If the screw is turned down too far when the voltage regulator is adjusted, the spring support will not follow the screw back up when it is turned out. In such a case, turn the screw out to get clearance. Then bend the spring support up and make the adjustment.

On double-contact regulators, voltage adjustment is made with the voltage regulator operating on the upper set of contacts. The difference in voltage between operation on the upper set and operation on the lower set can be increased by slightly increasing the air gap. The difference can be decreased by slightly reducing the air gap.

The voltage-regulator adjustment procedure varies with the particular type of regulator. On some regulators, you increase the voltage by increasing the spring tension or air gap. The spring tension is changed by bending the spring hanger, as shown in Fig. 28-10. To change the air gap, remove the regulator from the engine and reposition the fixed contact point.

The regulated voltage changes with the temperature of some generator regulators. Check the manufacturer's specification to see if the voltage regulation is correct for the temperature. Proper voltage-regulation settings vary widely with temperature. For example, on the typical Delco-Remy single-contact voltage regulator, the correct voltage can vary from 15.6 volts to 13.1 volts over a temperature range of 45 to 165°F [7.2 to 73.9°C].

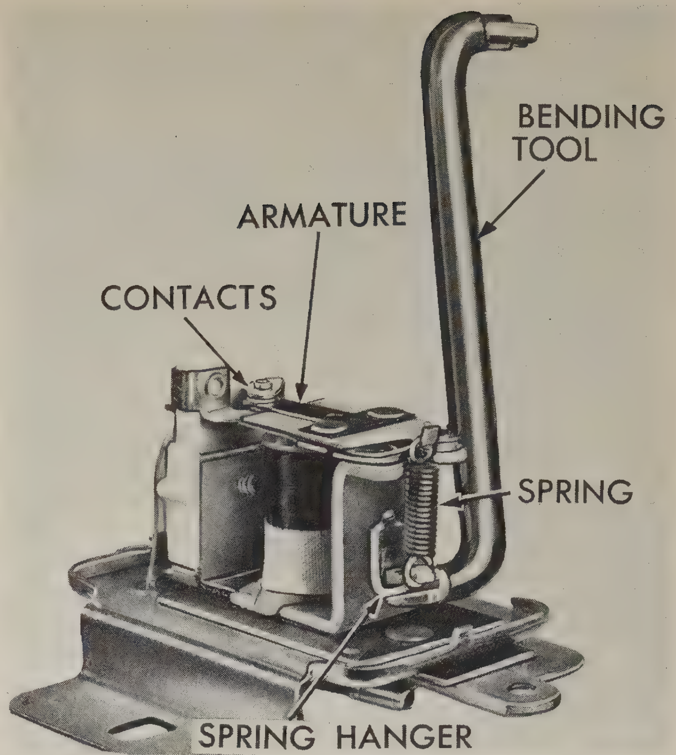


FIG. 28-10 Bending the spring hanger to change the voltage setting. (*Chrysler Corporation*)

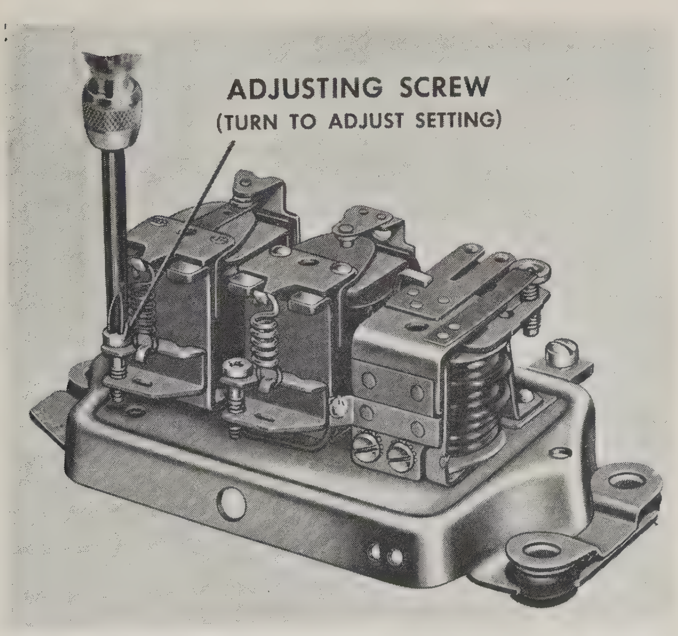


FIG. 28-9 Adjusting voltage-regulator setting by means of an adjusting screw. (*Delco-Remy Division of General Motors Corporation*)

○ 28-13 CURRENT-REGULATOR TESTS AND ADJUSTMENTS

A properly adjusted current regulator will permit the generator to produce up to its maximum rated current under heavy load. Two methods of checking the current-regulator setting can be used. With one method, an additional load is placed across the generator to assure current-regulator operation. With the second method, the voltage-regulator contacts are shorted out with a jumper lead. This method must not be used for current regulators with temperature compensation.

On current regulators with temperature compensation, connect an ammeter into the charging circuit. Connect an additional load (carbon pile resistor or extra lights) as shown in Fig. 28-11. Turn on all electrical equipment. Operate the generator for 15 minutes with the cover on. Then cycle the generator, and note the current setting. On current regulators without temperature compensation, connect an ammeter into the charging circuit. Remove the regulator cover, and connect a jumper lead across the voltage-regulator contacts. Turn on all lights and other electrical equipment, or load the battery as discussed earlier.

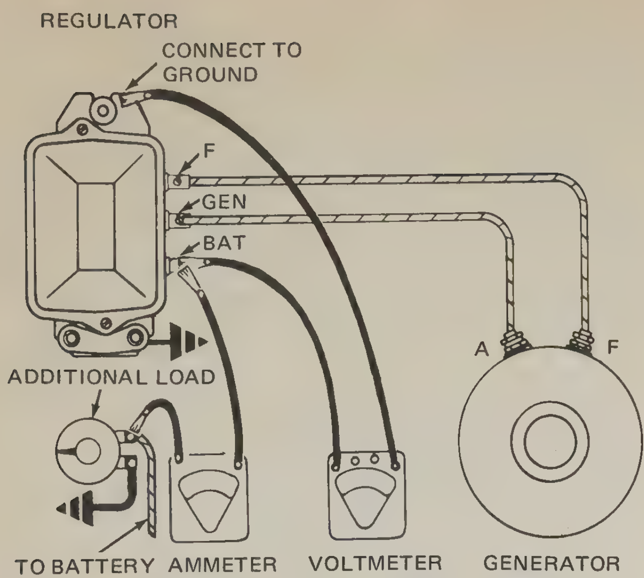


FIG. 28-11 Ammeter and jumper-lead connections for checking the current regulator using a jumper lead on regulators without temperature compensation. (*Delco-Remy Division of General Motors Corporation*)

Operate the generator at the specified speed, and note the output current on the ammeter.

The current setting of the current regulator is adjusted in the same manner as the voltage setting of the voltage regulator on Delco-Remy regulators. See Fig. 28-9. The maximum current reading will depend in part on the temperature of the regulator. At the temperature of 80°F [26.7°C] measured at the regulator cover, the current reading should usually be within 10 percent of the generator rated output. Too high a reading would indicate that the regulator is not limiting the output. Too low a reading indicates that the regulator is operating on too low a current. If the maximum current reading is too low, check to find out if the generator is defective. A generator current-output test was discussed in ○ 28-6. If the generator is all right, the current-regulator setting, or the current required to open the contacts, will have to be increased. To increase the setting, increase the relay spring tension or air gap.

If the maximum current reading is too high, decrease the current-regulator setting. For this adjustment, you should decrease the spring tension. The generator must be cycled by reducing the engine speed or field current enough to open the cutout-relay contact after each adjustment. Retest the new setting after each adjustment with the regulator cover in place.

○ 28-14 GENERATOR-REGULATOR SERVICE Many charging-system problems can be corrected by changing the spring tension and air gap on the individual relays in the generator regulator. Also, it may be necessary to clean the relay contact points.

Although it is possible to recondition most regulators, this can be time-consuming. There may be times when you make one adjustment only to find that another adjustment is needed. Because time is valuable in the service business, the procedure in most shops is to replace defective generator regulators rather than take the time to repair them. Usually, a new or rebuilt regulator can be obtained for less than the labor cost of repairing a defective regulator.

Always try to obtain the manufacturer's specifications before you attempt to service a regulator. This step is important, because the electrical settings, methods of measuring temperature, and the manner in which adjustments are made vary considerably among regulators.

The checks and adjustments on regulators can be divided into two parts: those performed on the engine and those performed after the regulator has been removed from the engine. Air gaps and point openings change little in normal operation. However, electrical settings sometimes do require adjustment to meet changed operating conditions. Electrical settings can be made without removing the regulator. If the electrical adjustments cannot be made properly, the regulator should be removed so that air gaps and point openings can be checked and adjusted. Then the electrical setting can be checked, either off or on the engine. Many regulators which are discarded as defective would operate satisfactorily if only some slight adjustment were made.

○ 28-15 SERVICING REGULATOR CONTACTS Clean contact points are essential if the regulator is to operate properly. Dirty or pitted contact points will cause unsteady or erratic charging. The contacts can be reconditioned if they are not badly pitted.

The contact points on many regulators can be cleaned with a special file. A flat file should not be used to clean the flat contact points, because it may not touch the center of the contact, where most wear occurs. The contact points should be filed in the direction of the length of the armature.

You can clean the cutout-relay contact points with crocus cloth or flexible abrasive material. All oxide should be removed so that there will be no resistance between the contacts. As a final step, the contact surface should be washed with a nontoxic chemical cleaner to remove all foreign matter.

Never use emery cloth or sandpaper on regulator contacts. Particles of the abrasive may become embedded in the contact surfaces and cause them to burn.

○ 28-16 CUTOUT-RELAY SERVICE The cutout relay should close when the generator voltage rises from 12.6 to 13.6 volts, so that the circuit is complete to the battery and charging can take place. However, specifications vary. The relay should open usually

when the generator output voltage falls enough for a reverse current of about 1 amp to flow.

The closing voltage can be varied by changing the relay spring tension. Some relays have coil springs and adjustable spring hangers as shown in Fig. 28-10. The cutout relay used on some other regulators has a flat spring attached to the armature as shown in Fig. 28-6. The end of the spring bears against a screw. To increase or decrease the spring tension, turn the screw out or into the threaded hole in the relay frame.

To adjust the air gap, the regulator should be removed from the engine. The procedure for making this adjustment varies. On some regulators, it is recommended that you lightly close the contacts with your fingers. Measure the spacing between the armature and relay core with a flat feeler gauge. Check the specifications. If the spacing is incorrect, loosen the screw and make the adjustment by raising or lowering the armature.

The contact point opening also should be checked. Use a flat feeler gauge to measure the spacing with the contacts fully open. Compare your reading with the manufacturer's specifications. To adjust the spacing, bend the armature stop. On other regulators, the contact spacing is adjusted by moving the stationary contact. Upon completion of these mechanical adjustments, the regulator should be installed on the engine and tested under actual operating conditions.

○ 28-17 CURRENT-REGULATOR ADJUSTMENTS The current regulator may require bench adjustment. If you are unable to obtain proper operation by adjusting the spring tension with the regulator on the engine while it is running, stop the engine and remove the regulator.

The air gap between the relay armature and core is measured with a round or wire feeler gauge. On the typical regulator, the spacing should be measured with the contacts barely touching. Adjust the spacing by loosening the stationary contact support and moving it up or down. Tighten the mounting screws. Reinstall and test the regulator after adjustment.

○ 28-18 VOLTAGE-REGULATOR ADJUSTMENTS Standard voltage regulators are adjusted in the same way as the current regulator. Push down on the armature until the contacts are barely touching, and measure the spacing with a round or wire feeler gauge. Loosen the screws and move the stationary contacts up or down as necessary.

To adjust the spacing, loosen the screw and insert a screwdriver in the slot provided. Move the screwdriver handle up or down to adjust the air gap and tighten the screw. The screw should be loosened enough to allow for the adjustment while maintaining a slight drag on the contact support.

The spacing between the upper contacts should be measured with the lower contacts closed. Using the special tool shown in Fig. 28-10, bend the upper contact arm to obtain the proper opening.

○ 28-19 GENERATOR SERVICE Troubles that can be traced to dc generators include no output, unsteady or low output, excessive output, and excessive noise. The majority of generator troubles can be cured by tightening the drive belt, replacing the brushes, repairing obviously bad connections, or lubrication. Other defects may require overhaul procedures, such as reconditioning the commutator, replacing field windings, or replacing bearings.

It is uneconomical, under some conditions, for a technician to overhaul a generator. If the trouble cannot be corrected quickly, either obtain a rebuilt generator or send the defective generator to an automotive electrical shop for rebuilding.

○ 28-20 GENERATOR TROUBLESHOOTING Table 28-2 (on page 280) lists the typical generator troubles and their probable causes and the checks or corrections to be made. Each trouble is discussed at the end of the table.

No Output The most likely causes of complete generator failure are listed in the table. To track down the defect, first make a visual inspection of the generator. Check the drive belt, making sure that it is tight and not badly worn. Check the wiring connections at the generator and regulator for tightness and corrosion. Clean and tighten as necessary.

Next, check the brushes and commutator for good electrical contact. If the generator has a cover band, remove it or look through the windows in the housing to inspect these parts. Look for sticking or worn brushes and gummed, dirty, or worn commutator. Figure 28-12 shows a badly worn and rough commutator. Check also for loose connections and frayed or broken wires.

Sticking brushes can sometimes be released by moving them in and out slightly with a screwdriver or other long, thin tool. Badly worn brushes, as well as any broken or frayed leads, should be replaced. Any loose screws should be tightened. If you cannot locate and correct the trouble easily, the generator must be removed and either disassembled for further tests or replaced.

If the commutator is dirty, it is often possible to clean it by using fine sandpaper. Hold the sandpaper against the rotating commutator with a piece of wood as shown in Fig. 24-35. Then blow out all the dust. If the commutator is worn or rough, it will have to be refinished or the armature will have to be replaced.

Unsteady or Low Output The causes of this condition are similar to the causes of no output. Begin with a good visual inspection and correct the things which

TABLE 28-2 dc GENERATOR TROUBLESHOOTING CHART

Condition	Possible Cause	Check or Correction
1. No output	a. Sticking brushes	Free; replace brushes and springs as necessary
	b. Gummy or dirty commutator	Clean; turn commutator and undercut mica if needed
	c. Burned commutator	Service commutator, and check the current-regulator setting
	d. Loose connections or broken heads	Tighten or solder connections; replace leads
	e. Grounded armature	Check with test light; repair or replace
	f. Open armature	Repair or replace
	g. Shorted armature	Check on growler; repair or replace
	h. Grounded field	Check with test light; repair or replace
	i. Open field	Check with test light; repair or replace
	j. Shorted field	Check with ammeter; repair or replace
	k. Grounded terminal	Replace insulation or terminal as needed
	l. Broken drive belt	Replace belt
2. Unsteady or low output	a. Loose or worn drive belt	Tighten or replace
	b. Sticking brushes	Free; replace brushes and springs as needed
	c. Low brush-spring tension	Retension or replace springs
	d. Dirty, gummy, or burned commutator	Clean; turn commutator, and undercut mica as needed; check armature for opens
	e. Out-of-round, dirty, worn, or rough commutator	Clean; turn commutator, and undercut mica as needed
	f. Partial short, ground, or open in armature	Repair or replace armature
	g. Partial short, ground, or open in field	Repair or replace fields
3. Excessive output	a. Grounded field circuit—type with field grounded in regulator	Check with test light; repair or replace
	b. Shorted field circuit—type with field grounded in generator	Test with ammeter; repair or replace
4. Noisy generator	a. Loose mounting or pulley	Tighten
	b. Worn or dirty bearings	Clean or replace
	c. Improperly seated brushes	Seat brushes properly

are easily accessible, such as the drive belt, electrical connections, and leads. If necessary, check and service the commutator to improve the electrical contact between it and brushes. When these steps do not correct the trouble, remove the generator for further work or replacement.

Excessive Output Excessive generator output is caused by a short circuit in the field winding or circuit which causes the field current to bypass the regulator. As a result, the regulator cannot control the output. In a generator which has the field grounded through the regulator, this short circuit can result from a grounded field circuit within the generator. In a generator in which the field is grounded directly and the regulator is the ungrounded side of the field winding, a short circuit between the field and armature lead could produce the same results.

The causes of excessive output can be detected quickly and easily by making resistance tests in the field circuit. In most cases, it will be necessary to remove the generator and disassemble it to make the repair.

Generator Noise There is some noise in any generator. However, noise may become excessive from such conditions as a loose mounting, a loose drive pulley or fan, worn or dry bearings, and improperly seated brushes.

To locate the cause of noise, remove the drive belt and rotate the pulley on the generator by hand while listening closely. A loose pulley or fan should show up immediately. You would be able to feel it wobble on the shaft. In this case, the nut on the front of the shaft should be tightened.

In many cases, excessive generator noise is due to worn or dry bearings, and the condition will become progressively worse with use. Try lubricating the

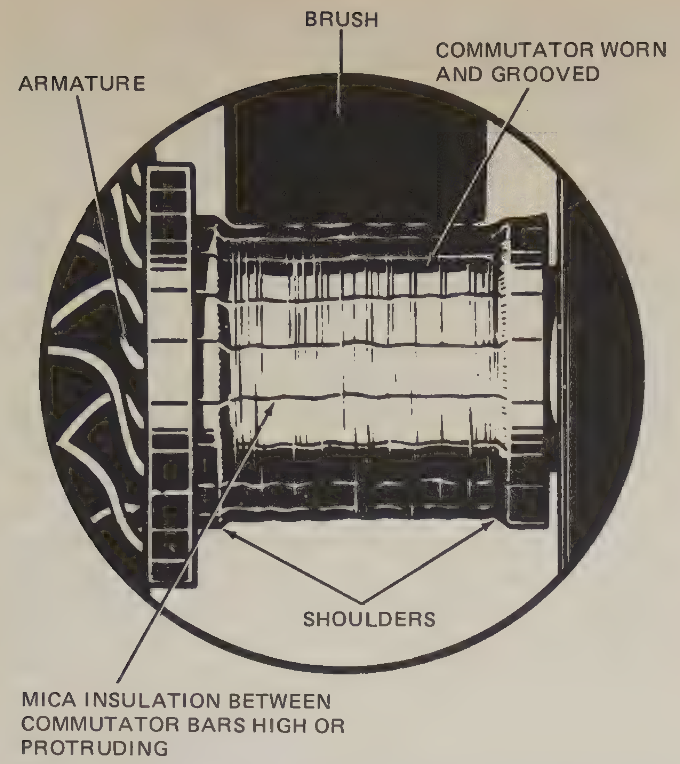


FIG. 28-12 A worn, grooved, and rough commutator with high mica. A commutator in this condition requires turning and undercutting of the mica.

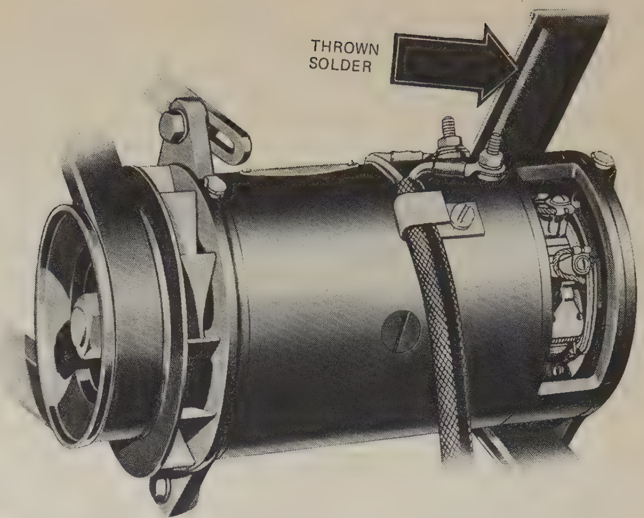


FIG. 28-13 Thrown solder on the cover band indicates the generator has been overloaded.

bearings if this can be done easily. However, some generators have sealed bearings, which should not be lubricated.

New brushes may produce excessive noise until they become seated. Check to see if the contours of the brushes match the commutator. If not, the brushes should be seated. If the brushes are improperly positioned, remove and reinstall them correctly.

○ 28-21 MECHANICAL INSPECTION OF GENERATORS The brushes, commutator, and wiring should be examined and the generator should be lubricated as needed. The cover band should be removed (on generators so equipped) so that the brushes and commutator can be checked.

The brushes should be free in their holders, and they should make good clean contact with the commutator. The pigtail lead connections should be tight. There should be enough brush left to last until the next inspection.

If particles of solder, called "thrown solder," are found on the inside of the cover band in line with the bars of the commutator, it is an indication that the generator has been overloaded (Fig. 28-13). The solder connecting the armature wires to the commutator bars has melted from the heat of excessive current flow. The generator must then be removed and disassembled. Usually, a new armature is installed. Sometimes the leads can be resoldered to the bars, and the commutator reconditioned. In all cases of thrown solder, the current-regulator setting must be checked and adjusted. Thrown solder may be the result of too high a current-regulator setting.

○ 28-22 GENERATOR REBUILDING The procedures for generator removal, disassembly, reassembly, and reinstallation vary with different applications and generator types.

○ 28-23 GENERATOR WIRING, INSULATION, AND FUSES Fuses of the proper current-carrying capacity should be installed in charging and electrical circuits wherever required. The fuses will protect electrical equipment against damage from excessive overloading or from accidental short circuits or grounds.

All connections in the charging circuit must be clean and tight. Loose or corroded connections cause high resistance and may result in serious damage to equipment owing to excessive voltage. All soldered connections should be made with rosin-core solder. Never use acid-core solder on electrical connections. Acid-core solder may cause corrosion to form on the connection. Rosin is a hard yellow substance made from the sap of pine trees and will not cause corrosion and faulty connections.

In wiring small engines, stranded wire (cable) must be used to minimize breakage due to vibration. All wiring should be supported at enough points to prevent any motion, since looseness would cause chafing and wear of the insulation.

For 24-volt systems, wire with thicker insulation must be used to protect against the higher voltage. Failure to insulate the wiring properly may result in serious damage because of the great amount of power available from the battery.

Terminals at the ends of wires must have ample current-carrying capacity and be sufficiently strong

to withstand vibration. Wires should be supported as close to terminals as possible.

Whenever generator wiring is installed, wire of sufficiently large size must be used to carry the maximum current the length of the circuit without excessive voltage drop. In two-wire insulated systems, the total length of wire in the circuit must be taken into account. Smaller wire can be used in the generator field circuit, since the current carried is comparatively small. It is only about 1 to 3 amps, depending upon the voltage of the system.

STARTER-GENERATORS

○ 28-24 STARTER-GENERATOR SERVICE In Chap. 24, we covered the servicing of the starter-generator, emphasizing the starter. Now let us consider the servicing of the generator part of the combination unit. Figure 28-14 is a sectional view of the starter-generator.

If generator output is low or zero, first check the ground strap between the voltage regulator and frame to make sure it is not disconnected or broken. Then check the commutator, brushes, and internal connections of the generator. Sticking brushes, a dirty or gummy commutator, or poor connections may prevent generator output. If everything appears to be in good condition in the generator, it is possible that the trouble is in the regulator. The regulator should be checked as explained later.

Because the starter-generator is in continuous operation all the time that the engine is running, the starter-generator should be checked periodically. The tougher the operating conditions, the more frequently the starter-generator should be checked. Frequent starts and stops, excessively long cranking periods due to hard starting, excessively dirty or moist operating conditions, heavy vibration from the engine or

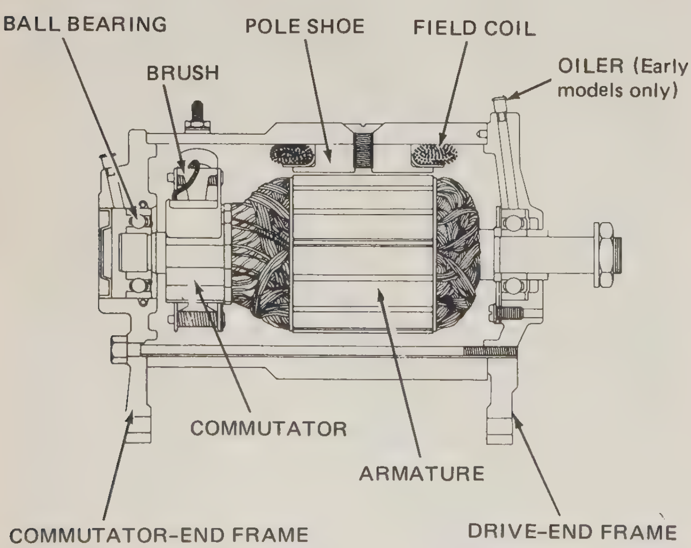


FIG. 28-14 Sectional view of a starter-generator. (*Kohler Company*)

surrounding machinery—all these make it necessary for the starter-generator to be checked frequently. In checking, you should look at the brushes, commutator, drive belt, and electrical wiring and connections. Following are typical recommendations from a manufacturer.

Brushes Brushes should be checked after about every 200 hours of operation. On the unit shown in Fig. 28-14, this requires removal of the two through bolts and the commutator end frame. Some starter-generators have windows in the brush end of the frame; these can be exposed for inspection of the brushes by removal of a cover band. Brushes should be in good condition and making good contact with the commutator. If they are worn down to less than one-half of their original length, they should be replaced. Proper brush-spring tension is important and can be measured with a spring scale. If the tension is not correct or if the springs appear blued or burned, replace them.

Commutator The commutator should be examined for glaze or dirt. It can be cleaned with #00 sandpaper. One way to do this is to put the armature in a lathe and, while it is rotating, hold the sandpaper against the commutator. On starter-generators with a cover band or windows in the end frame, stick the sandpaper through the window, as shown in Fig. 24-35, while the engine is driving the starter-generator. If the commutator is rough, is out-of-round, or has high mica, the commutator should be turned down in a lathe. See Fig. 24-38. Then the mica should be undercut, as shown in Fig. 24-39.

Never use emery cloth to clean the commutator. Particles of emery can become embedded in the commutator and cause rapid brush wear.

Drive Belt Make sure the drive belt is in good condition and is adjusted to the proper tension. Low belt tension will allow the belt to slip so that poor cranking and low generator output will result. Belt slippage will quickly wear out the belt. On some installations, belt tension is correct if you can push the belt in 1/2 inch [12.7 mm] halfway between the pulleys. Adjust the belt by loosening the bolt that holds the starter-generator tight, and swing the unit in or out to get the correct tension. Then tighten the bolt.

Lubrication Some starter-generators are equipped with sealed ball bearings and require no lubrication. Other units have hinge-cap oilers which require 8 to 10 drops of light engine oil after every 100 hours of operation. Whenever a starter-generator is disassembled, the bearings should be examined for wear. If worn, they should be discarded and new bearings installed. Sealed ball bearings should not be washed in solvent. This will wash out the lubricant and

thereby ruin the bearing. However, unsealed ball bearings should be washed in lubricant, dried, relubricated, and tested to see if they are in good enough condition to be reused. Never spin a bearing with compressed air to dry it. This will ruin the bearing.

○ 28-25 STARTER-GENERATOR REGULATOR SERVICE Figure 28-15 shows one model of starter-generator regulator with the cover removed so the two units inside can be seen. Several models of this type of regulator are used. When you have the job of checking and adjusting these regulators, refer to the manufacturer's instructions. The procedures required and the specifications to which the regulator should be set vary with different models. As a typical example of how to check and adjust a starter-generator regulator, let us look at the procedures for checking and adjusting the regulator shown in Fig. 28-15.

The connections to the regulator, including the ground connection, must be tight and clean. A loose ground connection, for example, will cause poor regulator operation.

If the regulator contact points become dirty and burned, there will be excessive resistance in the generator field circuit. The result is that generator output will be low. This could lead to a run-down battery. You can clean the contacts with a fine-cut file. This requires loosening of the screws holding the upper contact assembly in place so the assembly can be temporarily moved to one side or removed (Fig. 28-16).

Never use sandpaper or emery cloth to clean contacts. Particles of sand or emery can become embedded in the contact and prevent normal regulator action.

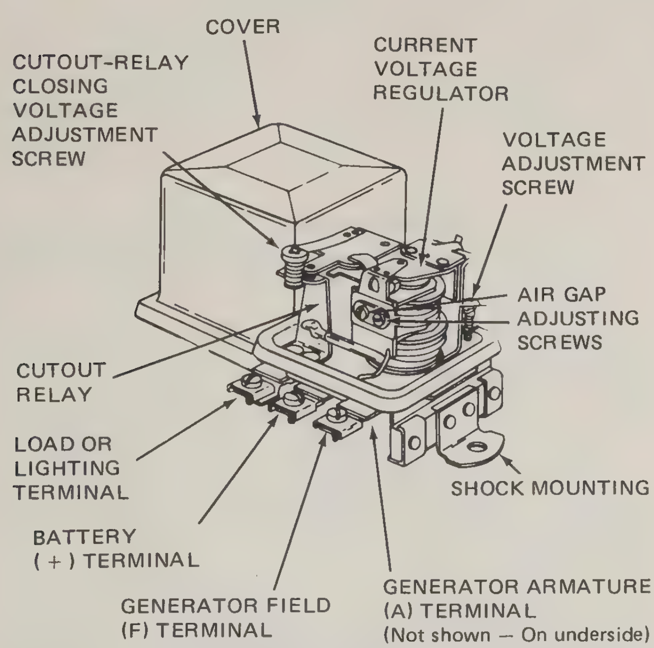


FIG. 28-15 Current-voltage regulator with cover removed to show adjustment required. (*Kohler Company*)

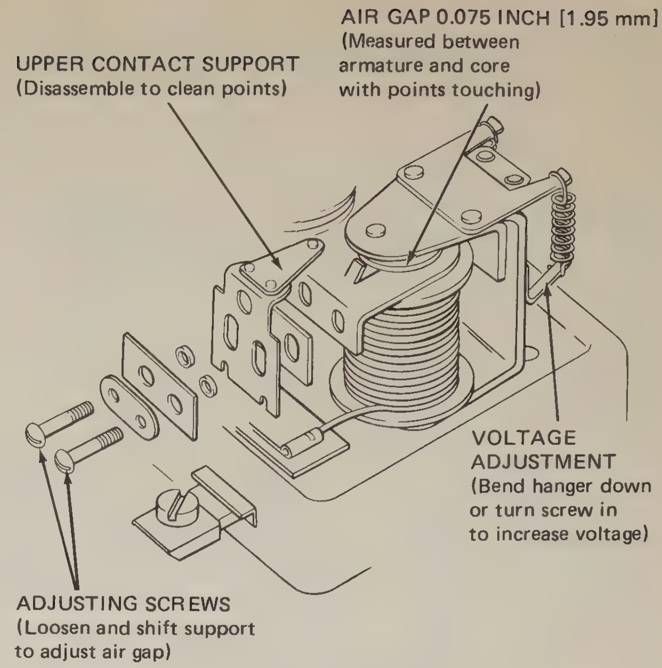


FIG. 28-16 Current-voltage regulator unit, showing adjustments. (*Kohler Company*)

Cutout Relay The cutout relay requires three checks and adjustments: those of air gap, point opening, and closing voltage. To make the air-gap and point-opening checks, disconnect the battery.

Air Gap See Fig. 28-17. Put a finger on the armature directly above the center of the winding, and press down on the armature until the points just close. Measure the air gap between the armature and the center of the winding core. On the model shown, this

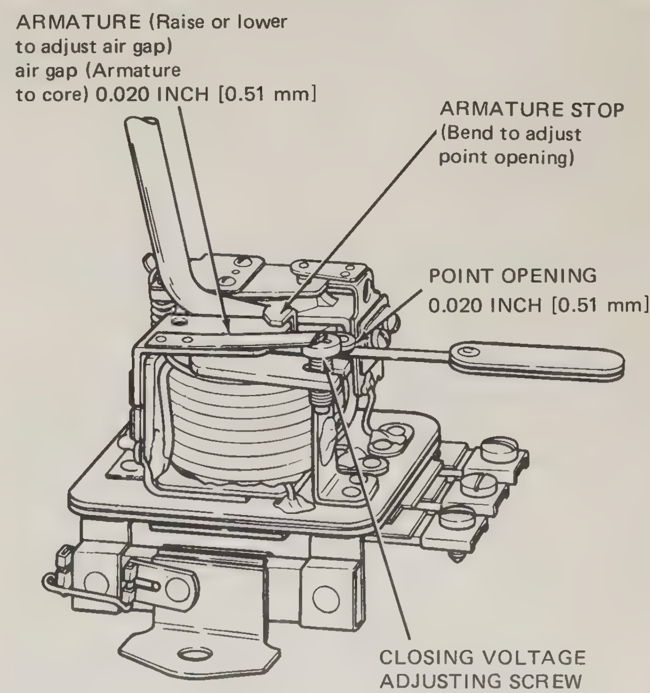


FIG. 28-17 Cutout-relay adjustments. (*Kohler Company*)

should be 0.020 inch [0.51 mm]. Adjust by loosening the two screws attaching the armature hinge to the frame and by raising or lowering the armature assembly.

Point Opening Release the armature and measure the point opening, as shown in Fig. 28-17. On the model shown, this should be 0.020 inch [0.51 mm]. Adjust by bending the upper armature stop.

Closing Voltage Connect the battery. Then connect a voltmeter from the generator terminal to ground. Start the engine and slowly increase its speed, noting the increase in voltage. Watch for the points to close, and read the voltage at this instant. The voltage should be adjusted, if it is not correct, by turning the closing-voltage adjusting screw (Fig. 28-17). Turning it to increase the tension of the flat spring increases the closing voltage. Recheck the closing voltage after each adjustment by slowing the engine until the points open and then increasing the speed again.

Current-Voltage Regulator This regulator requires two adjustments: those of the air gap and the operating voltage.

Air Gap See Fig. 28-16. Adjust by loosening the two adjusting screws and raising or lowering the upper-contact-point assembly. Adjustment is correct when the specified air gap is attained with the contact points just touching. Tighten the screws and recheck the air gap.

Operating Voltage This regulator operates on both generator voltage and generator output current. The regulator must be at operating temperature before the operating voltage is checked. This requires that the engine be operated for about 20 minutes so the regulator can warm up. Make the operating-voltage check with the regulator cover on. Because the voltage varies greatly with the current output, you must measure the operating voltage at a specified current output. For example, one model regulator, with a 3-amp current output, will regulate at 14.4 volts. However, with a 6-amp current output, it will regulate at only 13.2 volts.

Refer to the manufacturer's instructions for the specific regulator under test so you will know how to connect the meters to make the test. Adjust by bending the lower spring hanger down to increase the voltage setting or up to lower the voltage setting. Some regulators have a screw adjustment, similar to that shown in Fig. 28-17, for the cutout relay. Turning the screw in or out changes the voltage setting.

After each adjustment, put the regulator cover back into place. Slow the engine until the contact points of the cutout relay open, and bring the engine back up to speed. Then recheck the voltage setting.

ALTERNATORS

○ 28-26 SERVICING FLYWHEEL ALTERNATORS

Many small engines use alternators to furnish current for charging the battery and handling external electrical loads, such as lights. These alternators often are built into the engine itself. They are called flywheel alternators, because they use the flywheel as part of the alternator. Figure 28-18 shows a typical flywheel-alternator charging system. The flywheel has a series of magnets which whirl past the stationary coils (the stator coils) located around the outside of the flywheel. We explained how flywheel alternators work in Chap. 27. Now we will describe procedures for diagnosing and correcting troubles in small-engine flywheel alternators.

Because the flywheel alternator has no separate moving parts, it rarely requires service and seldom causes trouble. We will see what possible troubles might occur with flywheel alternators and how to find out what is causing the trouble.

○ 28-27 CAUTIONS FOR ALTERNATOR SERVICE

There are certain cautions to observe when working on alternator charging systems.

1. Keep all electrical connections clean and tight, and keep wires intact. High resistance due to poor battery connections will cause excessively high charging rates and cause the battery to use too much water.
2. All regulator checks and adjustments must be made under specified conditions.
3. Do not connect the battery backwards. Reversed battery connections may damage the rectifiers, wiring, or other components of the charging system. Battery polarity should be checked with a voltmeter to be sure which terminal post is connected to ground before reinstalling battery.
4. If booster batteries are used for starting the engine, they must be connected properly to prevent damage to the electrical system.
5. Anything that affects the battery or regulator affects voltage regulation.
6. Do not use batteries of higher-than-system voltage either to boost a battery of lower voltage or in starting. For example, do not jump-start an engine that uses a 6-volt battery with a 12-volt battery.
7. Alternators must not be operated on open circuit with the field winding energized. High voltages will result, causing possible rectifier failure. Make sure all connections are tight.

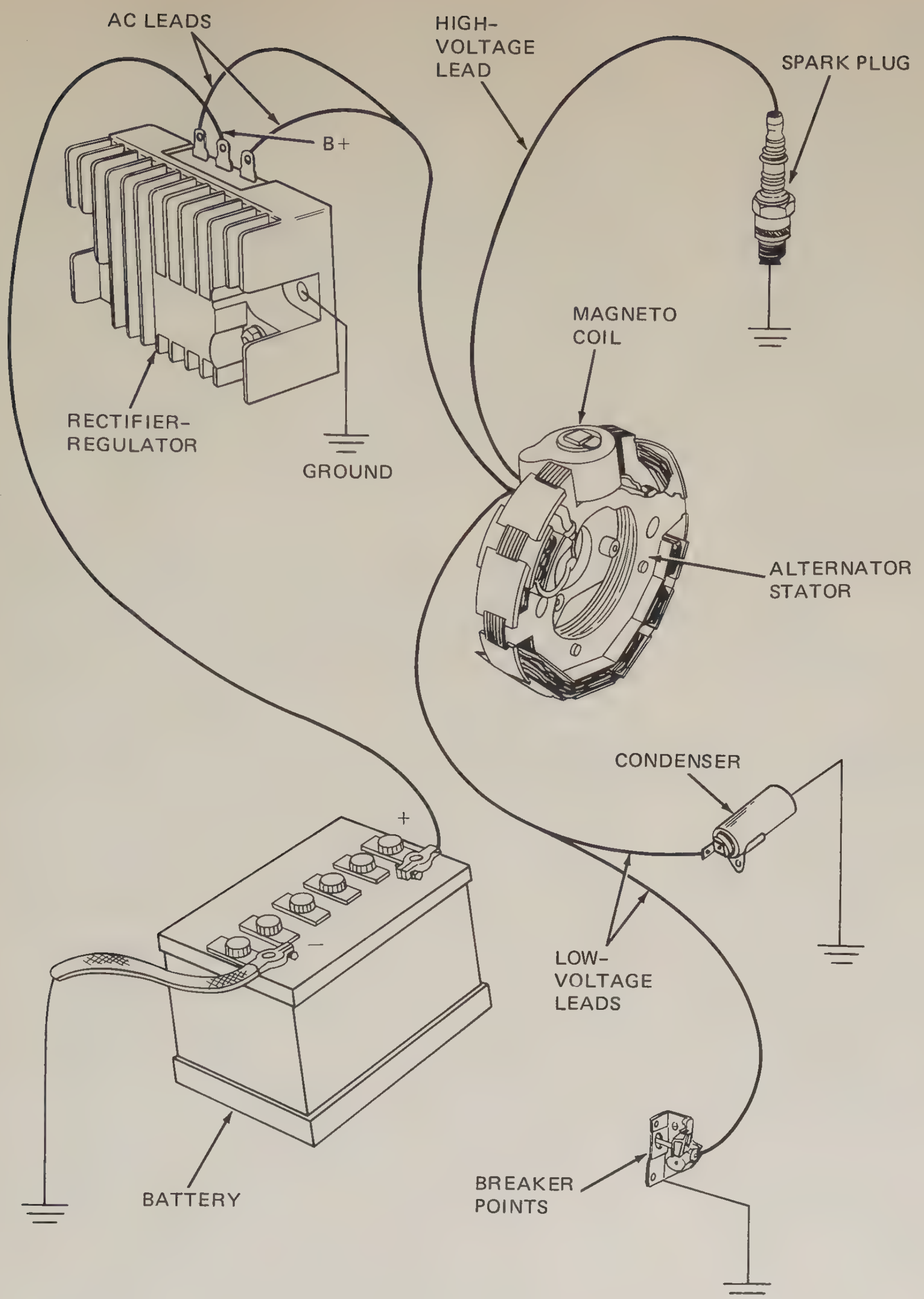


FIG. 28-18 A typical flywheel-alternator charging system. (*Kohler Company*)

8. Do not attempt to polarize the alternator. No polarization is required. Any attempt to polarize may result in damage to the alternator, regulator, or electrical circuits.
9. The field circuit must not be grounded at any point. Grounding of the field will damage the regulator. If the field lead from the regulator to the alternator is grounded, the battery will charge excessively.
10. Grounding the alternator output terminal may damage the alternator and/or circuit components even when the system is not in operation. A short circuit between the stator leads to the rectifier will show a discharge on the ammeter, and an undercharged battery will result.

○ 28-28 SERVICING THE FLYWHEEL-ALTERNATOR CHARGING SYSTEM The following procedures are used to check a flywheel-alternator charging system that uses a rectifier-regulator. There are many different arrangements. You should look up the specifications and specific procedures to use for any alternator in the manufacturer's service manual. With the correct information, you will be able to make the checks quickly and in the correct way. Incorrect checking procedures can damage equipment.

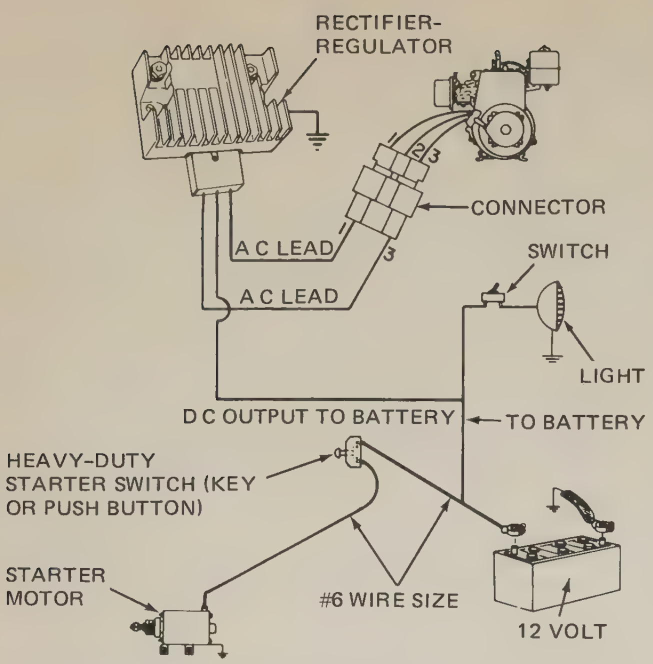


FIG. 28-19 Wiring circuits for a 7-amp flywheel alternator. (*Tecumseh Products Company*)

The system for which the following checks are to be made is shown in Fig. 28-19. There are two basic conditions that require checking: no charging current to the battery and battery overcharging.

No Charge to Battery If no charging current is going to the battery and the battery is weak or discharged (check battery to be sure), disconnect the B+ terminal wire. Connect a dc voltmeter from this lead to the case of the rectifier-regulator as shown in Fig. 28-20. Run the engine near full throttle, and read the voltage. If it is above 14 volts, the charging system is satisfactory. The trouble may be in the ammeter or connections in the circuit.

If the voltage is less than 14 volts but greater than zero, there probably is some defect in the rectifier-regulator. You can try another rectifier-regulator to see if this clears up the trouble, or you can check further. If there is no voltage at all, then the trouble can be in either the stator or the rectifier-regulator.

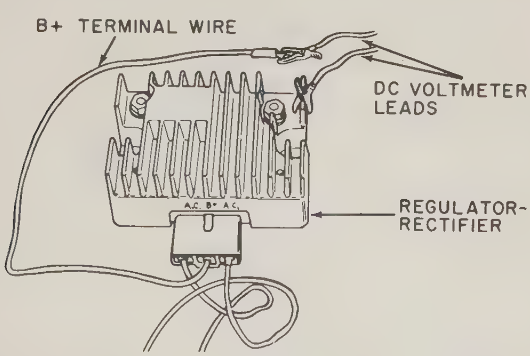


FIG. 28-20 Connecting voltmeter leads to check system voltage. (*Tecumseh Products Company*)

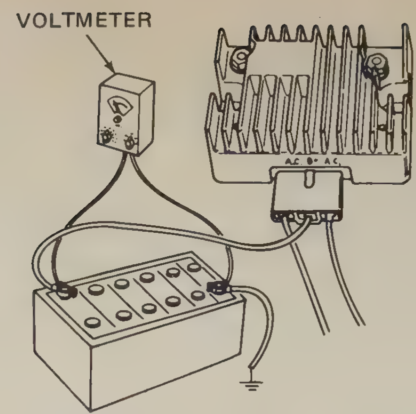


FIG. 28-21 Checking voltage at the battery. (*Tecumseh Products Company*)

Isolate the trouble by reconnecting the battery and checking the voltage between the two battery terminals, as shown in Fig. 28-21, with the engine operating near full throttle. If the voltage is 13.8 volts or higher, turn on a load such as the lights to reduce the voltage below 13.6 volts. If the charging rate increases, the system is in good condition. If the charging rate does not increase, the stator or rectifier-regulator is at fault and a further check must be made.

If the system has no ammeter, connect a test ammeter into the circuit when making the above test.

Disconnect the plug from the rectifier-regulator and test the ac voltage (use an alternating-current voltmeter) as shown in Fig. 28-22, with the engine running near full throttle. If the voltage reads less than 20 volts, the stator is defective. If the voltage reads more than 20 volts, the rectifier-regulator is defective.

If tests indicate the rectifier-regulator is at fault, it should be replaced. This is a sealed unit and cannot be serviced in the field. If tests show the stator is at fault, the trouble probably is due to an open or ground. The coils must be replaced. This requires partial disassembly of the engine. There also is the possibility that the flywheel magnets have weakened. However, this is a rare occurrence. The magnets can be tested with a screwdriver as shown in Fig. 26-25. Procedures vary for the disassembly of

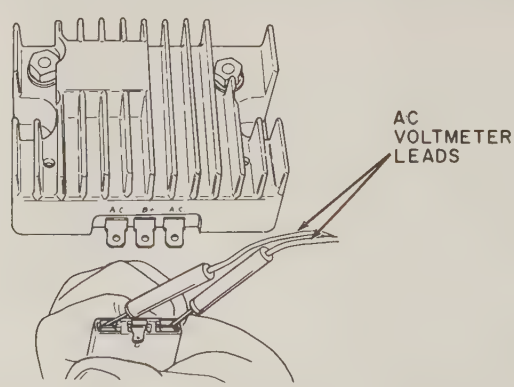


FIG. 28-22 Checking voltage of stator winding with an ac voltmeter. (*Tecumseh Products Company*)

different engines, so refer to the shop manual covering the engine being serviced. A general disassembly procedure for small engines is covered in later chapters.

Battery Overcharging This condition is probably due to a defective rectifier-regulator. You can check with a dc voltmeter connected as shown in Fig. 28-21 with the engine operating at nearly full throttle. If the voltage goes over 14.7 volts, the regulator is not functioning and the rectifier-regulator must be replaced. If the voltage remains under 14.7 volts, the system is functioning satisfactorily. There may be some trouble in the battery, such as a shorted cell, which causes the charging rate to remain high. Battery checking is described in Chap. 22.

REVIEW QUESTIONS

1. What are the four general types of complaints made about charging systems?
2. What can cause a high charging rate?
3. What are the causes of a low charging rate?
4. What is the meaning of no ammeter reading?
5. What can be wrong if the charging indicator light does not work?
6. How do you polarize a generator?
7. How do you make a generator output test?
8. Describe how to make a generator voltage test.
9. Explain how to test the cutout relay.
10. Explain how to adjust the cutout relay.
11. What is a closing-voltage test?
12. Explain how to test the voltage regulator.
13. Describe how to clean the contact points in the generator regulator.
14. What can cause a generator to be noisy?
15. Describe how to perform a mechanical inspection of the generator.
16. How do you check a fuse?
17. Explain how to clean the commutator of a starter-generator.
18. What two adjustments are made on the regulator for the starter-generator?
19. What is the danger of grounding the field circuit of an alternator?
20. What can happen if the alternator output circuit is open while the field winding is energized?
21. When the engine is running at full speed and the voltage of the flywheel alternator is above 14 volts, what is the condition of the charging system?
22. What is most likely to fail in the flywheel alternator?
23. What parts must be removed from the engine to install a new stator coil?
24. Can new magnets be installed in the flywheel of a flywheel alternator?
25. How can you test the strength of the flywheel magnets?

SELF PROJECT

Many different types of charging systems are used on small engines. For example, there is the starter-generator, the dc generator, the flywheel alternator, and the separate alternator. Get several manufacturers' shop manuals on late-model engines. Study the charging-system checks for the different makes of engines. Write out the specific checking procedures for the various types of charging systems. Put your sheets of paper with the checking procedure into your notebook. This will help you understand the various procedures and give you a permanent record of the procedures.

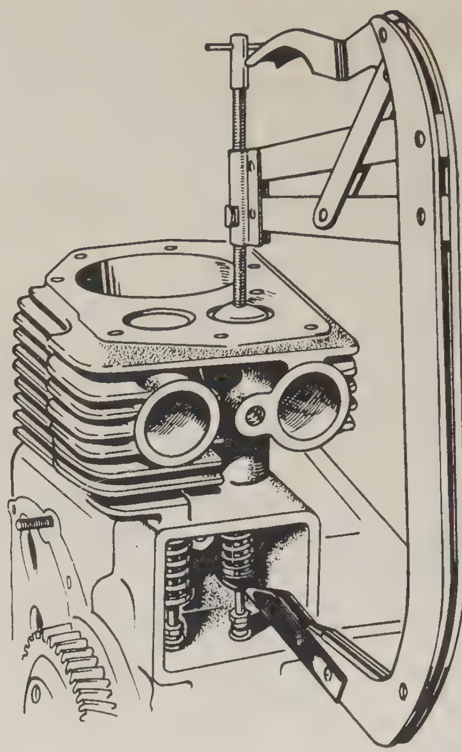
five ENGINE SERVICE

Part 5 of this book describes service operations on small engines. Included in Part 5 are servicing details on engine valves and valve trains, pistons and related parts, crankshafts, cylinder blocks, and cylinders. The servicing procedures discussed are aimed at correcting specific engine troubles.

There is another method of engine service called engine rebuilding. It involves bringing in old, worn engines and disassembling them completely. All worn parts are repaired or replaced, and the engine is completely rebuilt. Only those old parts that are still in good condition are reused. This results in an engine that is just about "as good as new."

Another way to service an engine is to purchase a "short block" from the manufacturer. This includes the cylinder block with all related parts such as pistons, piston pins, rings, connecting rods and bearings, crankshaft and main bearings.

There are four chapters in Part 5. These are as follows:



29
Chapter

Troubleshooting Small Engines

After studying this chapter, you should be able to:

1. **List the safety cautions to follow while troubleshooting small engines**
2. **List the operating cautions to follow while troubleshooting small engines**
3. **Explain what troubleshooting is and how analysis of a specific trouble can point to the possible causes and cures**
4. **Demonstrate how to troubleshoot a problem in a small engine**

○ 29-1 SAFETY Before we discuss small-engine troubleshooting, let us review engine safety. Every year people are injured by small engines and small-engine-powered equipment. When the operator or service technician observes basic safety precautions, the chances of injury are much less. Anyone operating or working on small engines and power equipment should always think about safety.

Power mowers, garden tractors, snowblowers, and other machines powered by small engines have become so commonplace that we may forget the potential dangers involved in servicing and operating such equipment. In the interest of safety, some general precautions are listed below as safety reminders. The best safeguard against accidents is to try to prevent them.

1. *Batteries:* Be careful when handling storage batteries. They contain acid that can eat through clothing and burn skin and cause blindness. A battery gives off highly flammable hydrogen gas while being charged. Avoid starting an engine until this gas is cleared from the area.
2. *Heat:* Keep away from hot exhaust parts and allow an ample cooling-off period before placing equipment in storage. Never cover a hot engine with flammable materials, such as rags, plastic sheeting, or the cover. They may catch fire.
3. *Electrical Shock:* While electrical energy from the ignition system may not be strong enough to cause actual injury, reaction to shock could cause you to pull away and come into contact with hot or moving parts. Keep hands away from the ignition system.
4. *Noise:* Keep the sound level as low as possible. Do not operate the engine without a muffler or with a faulty exhaust system. Exposure to excessive noise not only is tiring but also can lead to impairment of hearing.

○ 29-2 OPERATING CAUTIONS Improper operation of power equipment creates hazards that can lead to personal injury and property damage. To prevent accidents, become thoroughly familiar with a machine before operating it. Always wear safety glasses if appropriate. Read the instructions, know how to make emergency stops, practice driving the machine before putting it to work, and always use good common sense. Keep the following general operating precautions in mind:

1. Never allow children or other inexperienced persons to operate power equipment.
2. Never wear loose clothing such as scarves that could become entangled in the machine, choking you or pulling you into moving parts.
3. Make sure all guards and shields are in place and secure before starting.
4. To prevent unintentional starting when working on the equipment, always disconnect the spark-plug wire first.
5. Make sure hands, feet, and clothing are safely away from movable parts when starting.
6. Never attempt to start with drive engaged. Make sure it is shifted into neutral and the brakes are set.
7. Never tamper with the governor setting to gain more power. The governor establishes safe operating limits. Overspeed not only shortens the life of the equipment but also is extremely hazardous.
8. Keep people safely away from the operating area. Be especially watchful for children.
9. Watch for and avoid items such as stones and metal objects that could be picked up and thrown by blades. Clear the area of debris before operating.
10. Never attempt to unclog discharge chutes or to free stuck blades or any moving parts while the unit is operating. Stop the engine and disconnect the spark-plug wire first.
11. Never let a machine idle unattended even for a brief moment. Stop the engine whenever you leave the machine.
12. Watch out for and avoid steep inclines that could cause the machine to tip over.

○ 29-3 DEADLY EXHAUST GASES When operating, internal-combustion engines discharge carbon monoxide as part of the exhaust gases. Carbon monoxide is very dangerous, because it is odorless and hard to detect. Exhaust gases can cause death if inhaled for a short time. Always observe the following precautions:

1. Never operate an engine inside a closed building or in any area where exhaust gases can accumulate.
2. Be careful not to breathe exhaust fumes when working in the vicinity of an engine.
3. Keep the exhaust system tight and components in good condition at all times. Noise also can be harmful.
4. If the engine must be operated inside a shop for test purposes, make sure the exhaust gases are piped safely outside.
5. Exhaust-system parts get very hot. Keep your hands, feet, and clothing away from these parts while the engine is running and for a long time afterward.
6. Never operate an engine near a building where exhaust gases could seep inside—for example, through an open window or door.

○ 29-4 FUEL HAZARDS Gasoline is such a common fuel that we easily forget that it is highly volatile, extremely flammable, and explosive as a vapor. Keep the following in mind when storing, handling, and using gasoline:

1. Store gasoline only in an approved red container on which "GASOLINE" is clearly marked in large letters. Never store gasoline in a glass or household type of plastic container. The container could be broken and a disastrous explosion and fire could result (Fig. 29-1).
2. Store gasoline only in well-ventilated areas where escaping vapors can be safely dissipated.
3. Store gasoline containers safely out of reach of children.

FIG. 29-1 Never store gasoline in a glass container.

4. Never store gasoline inside a home or in any area occupied by people. This can be extremely hazardous.

5. Do not store or pour gasoline near potential spark- or flame-producing equipment. Upon starting, appliances such as refrigerators and freezers can produce electrical sparks that will ignite gasoline vapors. Even a spark from a light switch can ignite gasoline vapors.

6. Never use gasoline as a cleaning fluid. Observe "no smoking" rules whenever in the vicinity of a gasoline storage area or gasoline-fueled equipment.

7. Never add gasoline to the fuel tank while the engine is running. Stop the engine and allow it to cool first, to prevent spilled gasoline from igniting on contact with hot parts or ignition sparks.

8. Make sure fuel lines and connections are tight and in good condition. This will prevent gasoline leakage and the resulting possibility of fire.

9. Avoid overfilling the fuel tank. To prevent the fuel from spilling and igniting on contact with the hot engine or an ignition spark, do not fill the tank completely.

○ 29-5 COMMON SMALL-ENGINE ABUSES Small engines are built to "take it." They have comparatively large crankshafts and bearings, for example, considering the horsepower they produce. A minimum requirement to meet government specifications is that these small engines should operate at full load and top speed for 1000 hours. This may not seem like many hours of operation, but consider this: Suppose you used a power lawn mower four hours a week for six months. This is only about 100 hours of operation a year. At this rate, the engine should last about 10 years. Whether it lasts this long, or longer, depends largely on how well the engine is maintained. Some abuses that shorten engine life include the following:

1. *Allowing Dirt to Get into the Engine.* This will result from inadequate servicing of the air cleaner and fuel strainer, from improperly replacing spark plugs, and from contamination of the fuel.

2. *Failure to Check the Crankcase Oil Level on Four-cycle Engines.* This failure can allow the oil to drop too low. The result is inadequate lubrication of the engine, which causes rapid engine wear and early engine failure.

3. *Failure to Feed the Two-Cycle Engine a Fuel-Oil Mixture.* Without oil, the engine is inadequately lubricated, resulting in rapid wear and early failure. Improper lubrication means either that the proper amount of oil is not put into the gasoline for engines using the fuel-oil mix or that straight gasoline is used by mistake. On engines with an oil-injection system, failure of the system to deliver oil to the intake port or to the bearings will cause rapid engine wear and early engine failure.

4. *Overloading the Engine.* Trying to make a small engine do a big engine's job is a sure way to shorten engine life. If you change the governor setting on a lawn mower so the engine will run faster and handle heavier loads, you will shorten the life of the engine. It will wear out rapidly. Overspeeding and overloading an engine are two ways to shorten engine life.

5. *Failure to Properly Store the Engine.* Many engines power machines that are in use only part of the year. When they are not to be used for several weeks or months, engines should be prepared for the idle period. Failure to do this can lead to early engine failure.

As a small-engine technician, you cannot see to it that all your customers give their small engines proper treatment. But when they bring their small engines to you for repair, you should know the various things that could cause rapid engine wear and early engine failure.

○ 29-6 TROUBLE DIAGNOSIS OF SMALL ENGINES When you are trying to fix an engine that will not start or will not operate properly, there are certain checks to make to locate the cause of the trouble. The two most common complaints people have about small engines is that they will not start and that they lack power. In addition, the engine may surge, repeatedly increasing in speed and then slowing down. Also, it may gradually lose power as it is operated, or it may misfire.

There are different ways to study this chapter. You can go through it page by page, just as you have studied the previous chapters. Perhaps a better way would be to take one complaint at a time. Read through the possible causes and checks or corrections, and then study the section later in the lesson that discusses the complaint.

Since a knowledge of trouble causes and corrections is particularly helpful, you will probably be referring to Table 29-1 many times. One way to help yourself remember the complaints, causes, and checks or corrections is to write each complaint, with its list of causes and corrections, on a separate 3 by 5-inch card. Carry the cards around with you. When you have any free time, you can take out a card and study it. Soon you will know the troubles, their causes, and their checks or corrections.

○ 29-7 NEED FOR LOGICAL PROCEDURE

After a trouble has been located in an engine, usually it is easy to eliminate the conditions causing the trouble. In other chapters, and later in this chapter, we discuss the various engine services and explain the corrections to be made to eliminate different causes of engine trouble.

This part of the chapter covers troubleshooting, the detective work that a skilled technician must do with a case of engine trouble. Careful analysis and thinking often are needed to find the cause of trouble. If a logical procedure is followed, the cause of the trouble can usually be found quickly. But haphazard guesswork wastes time and may cause you to overlook entirely the real cause of the trouble. Unless the real cause of trouble is found and corrected, the trouble will soon occur again.

A variety of complaints will bring a sick engine to you. Seldom does the owner have a clear idea of what is causing the trouble. Most complaints can be grouped under a few basic headings. These include engine will not crank, engine cranks but will not start, engine runs but misses, engine lacks power, engine overheats, engine uses excessive oil or gasoline, or engine is noisy.

Table 29-1 (on pages 294–296) lists the various engine troubles, together with their possible causes, checks to be made, and corrections needed. The troubles and possible causes are not listed in the chart in the order of frequency of occurrence. Item 1 (or item *a* under "Possible Cause") does not necessarily occur more frequently than item 2 (or item *b*). Also, note that the chart covers all types of engines. The cause listed for each complaint may not apply to the particular engine you are servicing. At the end of the chart we discuss in detail several of the complaints and what to do about them.

○ 29-8 ENGINE WILL NOT START

Failure of the engine to start could be due to lack of fuel, failure of the fuel to feed to the carburetor, failure of the carburetor to feed fuel to the air passing through the air horn to the engine, clogged air filter, clogged exhaust ports, defective ignition system, or internal engine damage. To check out the engine and locate the trouble, first make sure there is clean gasoline in the fuel tank. Next, make sure the vent in the fuel-tank cap is clear. If it is clogged, the engine may start but soon stop. This is because a clogged vent does not permit gasoline to flow rapidly enough from the fuel tank to the carburetor.

○ 29-9 COMPRESSION CHECK

Check the engine compression by slowly pulling the engine through the compression stroke with the starter as shown in Fig. 29-2. Be sure the ON-OFF switch is off. If the starter is of the rope-wind or rope-rewind type, you can judge the compression by the feel. For example, if the engine spins very easily, then there is little compression. This can be due to a loose cylinder head, defective head gasket, loose spark plug, cracked head or cylinder, broken piston rings, or broken piston. On four-cycle engines, loss of compression may be due to a defective valve that sticks open. First, check the spark plug. If it is tight, then look for other causes of trouble. Disassemble the engine only as necessary to find the trouble.

FIG. 29-2 Check engine compression by slowly pulling the engine through the compression stroke with the starter rope. (*Lawn Boy Division of Outboard Marine Corporation*)

An accurate check of the cylinder compression pressure can be made with a compression gauge, as shown in Fig. 29-3. To check the compression with the gauge, remove the spark plug and install the compression gauge in the cylinder in its place. Some gauges screw into the spark-plug hole. Others must be held there. Next, crank the engine for at least six revolutions, or until the compression-gauge needle stops rising. Compare the reading on the compression gauge with the engine manufacturer's specifications. This is important, because the specifications vary among different engine manufacturers.

If you cannot locate the manufacturer's specifications, here are a couple of general rules to use that indicate when an engine has good compression:

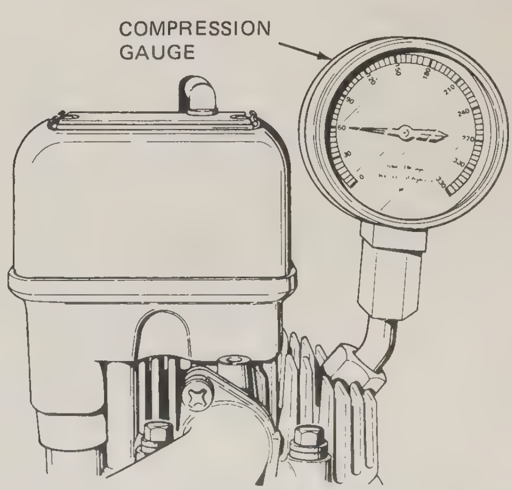


FIG. 29-3 Checking cylinder compression pressure with a compression gauge. (*Tecumseh Products Company*)

TABLE 29-1 ENGINE TROUBLESHOOTING CHART

Complaint	Possible Cause	Check or Correction
1. Engine will not crank	a. Run-down battery	Recharge or replace battery; start engine with jumper battery and cables
	b. Starting circuit open	Find and eliminate the open; check for dirty or loose cables
	c. Starter drive jammed	Remove starter and free drive
	d. Starter jammed	Remove starter for teardown and correction
	e. Engine jammed	Check engine to find trouble
	f. Transmission not in neutral, or safety-interlock switch out of adjustment	Check and adjust neutral switch if necessary
	g. (See also causes listed under item 3; operator may have run battery down trying to start)	
2. Engine cranks slowly but does not start	a. Run-down battery	Recharge or replace battery; start engine with jumper battery and cables
	b. Defective starter	Repair or replace
	c. Bad connections in starting circuit	Check for loose or dirty cables; clean and tighten
	d. (See also causes listed under item 3; operator may have run battery down trying to start)	
3. Engine cranks at normal speed but does not start	a. Defective ignition system	Make spark test; check timing, ignition system
	b. Defective fuel pump, no fuel, or overchoking	Prime engine; check accelerator-pump discharge, fuel pump, fuel line, choke, carburetor
	c. Air leaks in intake manifold or carburetor	Tighten mounting; replace gaskets as needed
	d. Defect in engine	Check compression or leakage, valve action, timing
	e. Ignition coil or resistor burned out	Replace
	f. Plugged fuel filter	Clean or replace
	g. Plugged or collapsed muffler or exhaust system	Clean or replace parts
4. Engine runs but misses—one cylinder	a. Defective spark plug	Clean or replace
	b. Defective distributor cap or spark-plug cable	Replace
	c. Valve stuck open	Free valve; service valve guide
	d. Broken valve spring	Replace
	e. Burned valve	Replace
	f. Bent push rod	Replace
	g. Flat cam lobe	Replace camshaft
	h. Defective piston or rings	Replace; service cylinder wall as necessary
	i. Defective head gasket	Replace
	j. Intake-manifold leak	Replace gasket; tighten manifold bolts
5. Engine runs but misses—different cylinders	a. Defective distributor advance, coil, condenser	Check distributor, coil, condenser
	b. Defective fuel system	Check fuel pump, flex line, carburetor
	c. Cross-firing plug wires	Replace or relocate
	d. Loss of compression	Check compression or leakage
	e. Defective valve action	Check compression, leakage, vacuum
	f. Worn pistons and rings	Check compression, leakage, vacuum
	g. Overheated engine	Check cooling system
	h. Restricted exhaust	Check exhaust, ports, muffler; eliminate restriction

TABLE 29-1 ENGINE TROUBLESHOOTING CHART (Continued)

Complaint	Possible Cause	Check or Correction
6. Engine lacks power—hot or cold	a. Defective ignition	Check timing, distributor, wiring, condenser, coil, and plugs
	b. Defective fuel system	Check carburetor, choke, filter, air cleaner, and fuel pump
7. Engine lacks power—hot only	a. Engine overheats	Check cooling system
	b. Choke stuck partly closed	Repair or replace
	c. Vapor lock	Use different fuel or shield fuel line
8. Engine lacks power—cold only	a. Choke stuck open	Repair or replace
	b. Cooling-system thermostat stuck open	Repair or replace
	c. Engine valve stuck open	Free valve; service valve stem and guide as needed
9. Engine overheats	a. Lack of coolant	Add coolant; look for leak
	b. Ignition timing late	Adjust timing
	c. Loose or broken fan belt	Tighten or replace
	d. Thermostat stuck closed	Replace
	e. Clogged water jackets	Clean
	f. Defective radiator hose	Replace
	g. Defective water pump	Repair or replace
	h. Insufficient oil	Add oil
	i. High-altitude, hot-climate operation	Adjust carburetor, ignition timing; keep radiator filled
	j. Valve timing late; slack timing chain has allowed chain to jump a tooth	Retime, adjust, or replace
10. Rough idle	a. Incorrect carburetor idle adjustment	Readjust idle mixture and speed
	b. (See also other causes listed under items 6 to 8)	
11. Engine stalls cold or as it warms up	a. Choke valve stuck closed or will not close	Open choke valve; free or repair choke
	b. Fuel not getting to or through carburetor	Check fuel pump, lines, filter, float, and idle systems
	c. Idling speed set too low	Increase idling speed to specifications
12. Engine stalls after idling or slow-speed operation	a. Defective fuel pump	Repair or replace fuel pump
	b. Overheating	(See item 9)
	c. High carburetor float level	Adjust
	d. Incorrect idling adjustment	Adjust
13. Engine stalls after high-speed operation	a. Vapor lock	Use different fuel or shield fuel line
	b. Carburetor venting or idle-compensator valve defective	Check and repair
	c. Engine overheats	(See item 9)
	d. Fuel-tank vent plugged	Clear vent
14. Engine backfires	a. Ignition timing off	Adjust timing
	b. Spark plugs of wrong heat range	Install correct plugs
	c. Excessively rich or lean mixture	Repair or readjust fuel pump or carburetor
	d. Engine overheats	(See item 9)
	e. Carbon in engine	Clean
	f. Valves hot or stuck	Adjust, free, clean. Replace if bad
	g. Cracked distributor cap	Replace
	h. Cross-firing plug wires	Replace
15. Engine run-on, or dieseling	a. Incorrect idle adjustment	Adjust
	b. Engine overheats	(See item 9)
	c. Hotspots in cylinders	Check plugs, pistons, cylinders for carbon
	d. Timing advanced	Adjust

TABLE 29-1 ENGINE TROUBLESHOOTING CHART (Continued)

Complaint	Possible Cause	Check or Correction
16. Too much HC and CO in exhaust gas	a. Ignition miss	Check spark plug, wiring, cap, coil, etc.
	b. Incorrect ignition timing	Check choke, float level, idle-mixture screw, etc., as listed in item 20
17. Smoky exhaust		
a. Blue smoke	Excessive oil consumption	(See item 18)
b. Black smoke	Excessively rich mixture	(See item 20)
c. White smoke	Steam in exhaust	Replace cylinder-head gasket; tighten cylinder-head bolts to eliminate coolant leakage into combustion chamber
18. Excessive oil consumption	a. External leaks	Correct seals; replace gaskets
	b. Burning oil in combustion chamber	Check valve-stem clearance, piston rings, cylinder walls, rod bearings
	c. High-speed operation	Operate engine slower
19. Low oil pressure	a. Worn engine bearings	Replace
	b. Engine overheating	(See item 9)
	c. Oil dilution or foaming	Replace oil
	d. Lubricating-system defects	Check oil lines, oil pump, relief valve
20. Excessive fuel consumption	a. High-speed operation	Operate engine slower
	b. Excessive fuel-pump pressure or fuel-pump leakage	Reduce pressure; repair pump
	c. Choke partly closed after warm-up	Open; repair or replace choke
	d. Clogged air cleaner	Clean or replace
	e. High carburetor float level	Adjust
	f. Stuck or dirty float needle valve	Free and clean
	g. Worn carburetor jets	Replace
	h. Carburetor leaks	Replace gaskets; tighten screws
	i. Cylinder not firing	Check coil, condenser, timing, spark plug, contact points, wiring
	j. Loss of engine compression	Check compression or leakage
	k. Defective valve action (worn camshaft, chain slack, or jumped tooth)	Check with compression, leakage, or vacuum tester
	l. Excessive resistance from connected equipment	Correct defects causing resistance
	m. Clutch slippage	Adjust or repair
21. Engine noises		
a. Regular clicking	Valve and tappet	Readjust valve clearance, replace noisy valve
b. Ping, or spark knock, on load or acceleration	Detonation due to low-octane fuel, carbon, advanced ignition timing, or causes listed under item 14	Use higher-octane fuel; remove carbon; adjust ignition timing
c. Light knock or pound with engine floating	Worn connecting-rod bearings or crankpin, misaligned rod, lack of oil	Replace bearings service crankpins, replace rod; add oil
d. Light, metallic double knock, usually most audible during idle	Worn or loose pin or lack of oil	Service pin and bushing; add oil
e. Chattering or rattling during acceleration	Worn rings, cylinder walls, low ring tension, or broken rings	Service cylinder walls; replace piston rings
f. Hollow, muffled bell-like sound (engine cold)	Piston slap due to worn pistons or walls, collapsed piston skirts, excessive clearance, misaligned connecting rods, or lack of oil	Replace or resize pistons; service cylinder walls; replace connecting rods; add oil
g. Dull, heavy metallic knock under load or acceleration, especially when cold	Regular noise; worn main bearings; irregular noise; worn thrust bearing knock on clutch engagement or on hard acceleration	Replace or service bearings and crankshaft
h. Miscellaneous noises (rattles, etc.)	Loosely mounted accessories: alternator, starter, water pump, etc.	Tighten mounting

Clinton suggests that on small general-purpose two-cycle engines, good compression pressure should be above 60 psi [4.22 kg/cm²]. For high output, two-cycle engines, such as chain saws and outboard engines, McCullock recommends that an engine have compression of at least 90 psi [6.33 kg/cm²]. For comparison, a new Yamaha 125-cc motorcycle engine has a compression pressure of about 120 psi [8.44 kg/cm²]. On engines with two or more cylinders, the compression in the lowest cylinder should be within 10 to 15 percent of the highest cylinder.

On kick starters, you can judge compression by the ease with which you can kick over the engine. If it kicks over too easily, the engine has lost compression for any of the reasons noted above.

If the engine uses a windup or an electric starter, you can judge the compression by the way the engine acts when it is cranked. With the windup starter, if release of the spring turns the engine over unusually fast or for a long time, you can suspect loss of compression. With an electric starter, an engine that has poor compression will spin abnormally fast.

When checking compression, listen for unusual squeaks, squeals, scraping, or knocking sounds. Any of these could mean worn bearings, scored cylinder walls or pistons, or broken rings or other parts. If you hear such noises, do not try to start the engine. Carefully check engine parts, disassembling the engine as necessary to examine them.

If the engine has normal compression, it will resist the kick starter or the pull of the rope—or act normally when starting is attempted with the windup or electric starter. Another sign of good compression on small two-cycle engines is a sucking sound when the engine is spun fast. This should be followed by a sort of cough as the engine stops after the spin, indicating that the engine is taking in air normally. If the engine has "easy-spin" starting, or a compression release, turn the engine backwards to check compression.

○ 29-10 IGNITION CHECK Try to start the engine by choking it, making sure the ON-OFF switch is turned on. Then crank the engine. If the engine has normal compression but will not start, then the ignition system or carburetor is probably at fault. Check the ignition system first by disconnecting the high-voltage lead from the spark plug. Pull back the rubber hood to expose the lead clip, or put a bolt into it to get metal contact. Hold the clip or bolt about 3/16 inch [5 mm] from the cylinder head, and crank the engine as shown in Fig. 26-1. If a strong spark jumps to the cylinder head, the ignition system is probably all right.

If no spark occurs, then the ignition system is probably at fault and should be checked as discussed in Chap. 26. Causes of trouble could be dirty or worn contact points or points out of adjustment. Defects in

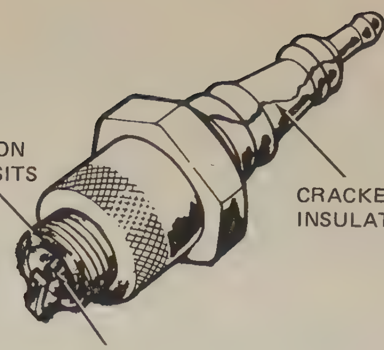


FIG. 29-4 Defective spark plug showing cracks, carbon deposits, and worn electrodes. (*Lawn Boy Division of Outboard Marine Corporation*)

the capacitor, high-voltage lead, ON-OFF switch, or magneto coil could also cause trouble.

If a spark does jump from the bolt or high-voltage-lead clip, examine the spark plug to see if it can deliver the spark to the engine cylinder. Remove the spark plug and reattach the high-voltage lead to it. Then lay or hold the spark plug against the cylinder head, as shown in Fig. 26-2. Crank the engine. If no spark jumps the gap, the spark plug is probably at fault. Examine it for cracks, black sooty deposits on the porcelain or electrodes, burned electrodes, or wide gap, as shown in Fig. 29-4. Any of these could prevent a good spark.

There is one other point to check. Remove the spark plug just after cranking the engine. If the end is wet with gasoline, then fuel is getting into the cylinder. Put your finger over the spark-plug hole in the head and crank the engine with the choke on, as shown in Fig. 29-5. If your finger gets wet, it is added evidence that fuel is getting through.

If the end of the plug or your finger does not get wet with gasoline, then the carburetor is not delivering fuel. The trouble could be due to clogged lines or nozzle, incorrect adjustment, or defective float system.

○ 29-11 CARBURETOR CHECK Try to adjust the carburetor. If this fails, then the carburetor will have to be removed for disassembly and repair. A typical

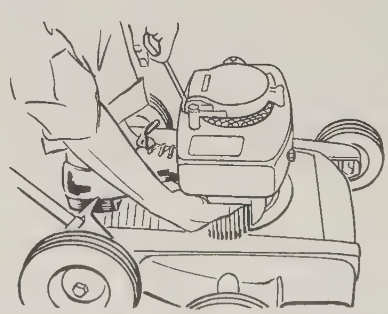


FIG. 29-5 Using thumb to feel if fuel is entering the cylinder head.

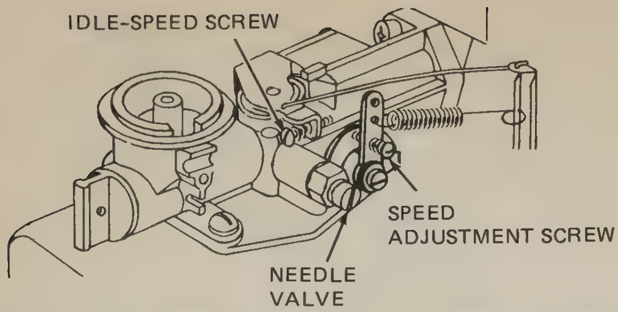


FIG. 29-6 Adjustment screws on a small-engine carburetor. (*Briggs & Stratton Corporation*)

adjustment procedure on a small-engine carburetor is as follows: Turn the needle valve, shown in Fig. 29-6, clockwise to seat the main-nozzle needle valve. Do not turn the needle-valve screw too tight. This might damage the seat or the needle, which would then require replacement. Back off the needle one and a half turns. Close the choke. Now crank the engine to see if gasoline appears in the cylinder, using a finger on the plug hole to check. If gasoline now appears, install the spark plug and try to start the engine. If it starts, open the choke as the engine warms up. If the engine runs roughly, it may be getting too much gasoline. Turn the needle valve in to produce a leaner mixture. After the engine is warmed up, turn the needle knob in until the engine begins to die from an excessively lean mixture. Then back out the needle valve about one-fourth turn. This should be the best adjustment for full-load operation.

Chapter 18 describes in detail the adjustment procedures for various types of carburetors.

○ 29-12 ENGINE STARTS BUT LACKS POWER A common cause of this trouble in two-cycle engines is clogged exhaust ports. Carbon that forms as a result

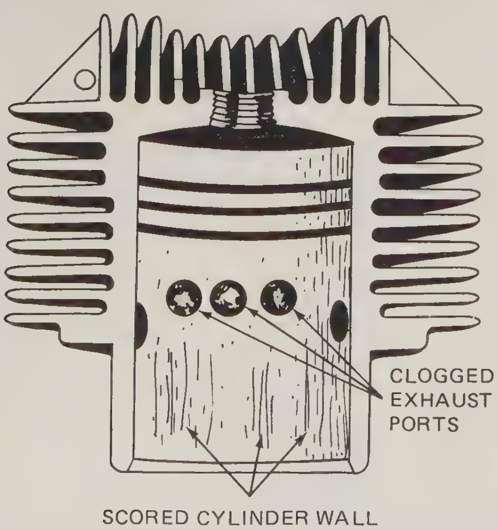


FIG. 29-7 Cutaway view of cylinder head showing scored walls and clogged exhaust ports, caused by carbon deposits in the exhaust ports.

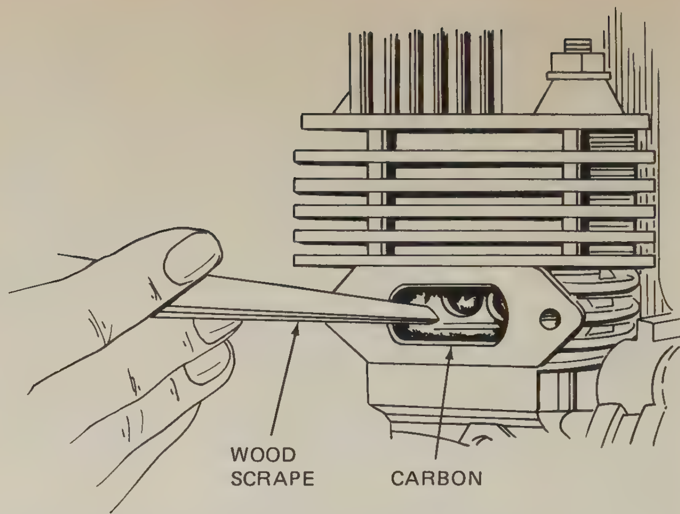


FIG. 29-8 Use a hardwood scraper or screwdriver to remove carbon from the exhaust ports.

of the combustion action in the cylinder often builds up in the exhaust ports, as shown in Fig. 29-7. As this buildup continues, the engine is less and less able to exhaust burned gases, and less fresh air-fuel mixture can enter the engine cylinder. This means that engine power is lost. If the deposits are not removed, the engine will barely run. To remove the carbon, take off the exhaust muffler. Turn the engine flywheel so the piston covers the exhaust ports. Then use a hardwood scraper, as shown in Fig. 29-8, to carefully scrape away the carbon. The piston will keep particles from falling into the cylinder, where they could cause trouble. Be extremely careful to avoid scratching the piston. Use compressed air to carefully blow out all loose particles from the ports.

On some two-cycle engines, the mufflers also tend to clog up with carbon. This carbon should be removed periodically.

If clogged exhaust ports are not the cause of lack of power, then check and adjust the carburetor. The carburetor may be supplying an overrich or overlean mixture.

○ 29-13 ENGINE DEFECTS If the lack of power is not due to clogged exhaust ports or faulty carburetor action, then the trouble is probably in the engine itself. It could be due to worn pistons or cylinders or to worn or broken rings. One other possible cause should be considered, and this is a defective reed valve in the crankcase. If the reed valve is broken or not seating properly, it may not hold compression in the crankcase. The result would be that not enough air-fuel mixture would be retained in the crankcase. The air-fuel charge going to the combustion chamber on intake would not be enough for the engine to develop full power. If the reed valve is broken, warped, or bent so it does not lie flat against the inlet holes, it should be replaced.

○ 29-14 ENGINE SURGES

This is a possible complaint on small engines with governors such as are used on lawn mowers. If the engine surges by repeatedly speeding up and slowing down, the trouble probably is in either the carburetor or the governor. Try adjusting the carburetor as explained in ○ 29-11. If this does not cure the trouble, then check the governor. Things to look for in the governor are binding of the linkage between the governor and the throttle valve, a weak or damaged governor spring, and worn or binding governor parts.

If engine speed is not correct, it can be adjusted on some engines by bending the linkage between the governor and the throttle valve. On other engines, adjustment is made by changing governor springs. Do not attempt to change the speed by stretching the governor spring. A stretched spring will not hold its new set, and engine operation will be unsteady. Governor service is covered in detail in Chap. 18

○ 29-15 ENGINE LOSES POWER

If the engine starts off properly but gradually loses speed as it warms up, the most likely source of trouble is the fuel system. For example, the vent in the fuel-tank cap might be clogged, or the needle in the float bowl might be stuck. In either case, too little gasoline gets through to the carburetor, and the engine slows down because it is fuel starved.

Lack of lubrication in the engine, for example, from failure to put oil in the gasoline of a two-cycle engine might cause loss of power as the engine warms up. This would soon cause complete engine failure from seized bearings or scored cylinder walls or pistons, as shown in Fig. 29-7.

○ 29-16 IRREGULAR FIRING

If the engine fires irregularly, the trouble could be a weak spark or poor carburetion. Check the spark by making a spark test. Replace the coil or capacitor, clean and adjust or replace contact points, and replace wires as necessary. Check and adjust the carburetor as already described.

A two-cylinder opposed piston engine may run fairly well when firing on only one cylinder if no load or a minimum load is applied to the engine but lose power quickly when a full load is put on the engine. If this situation should occur, first check that fuel is getting into the cylinder. Also, check the intake-manifold gaskets and connections for air leaks. If no problem is found, then check the ignition system for the cylinder that is misfiring. Again, if no problem is found and the engine continues to misfire, then check the compression. However, a lean air-fuel mixture is the most common cause of a two-cylinder opposed engine running on only one cylinder. Adjust the carburetor as described earlier in ○ 29-11.

REVIEW QUESTIONS

1. What cautions must you observe while working around batteries?
2. List the operating cautions that should be followed when working on small engines.
3. How can you prevent carbon monoxide poisoning?
4. Why does overloading a small engine shorten its life?
5. What is meant by trouble diagnosis?
6. What are the possible causes of an engine's failure to start?
7. Describe the procedure to make a compression check.
8. What is considered good compression on a two-cycle engine?
9. What is considered good compression on a four-cycle engine?
10. How much variation is allowed in compression pressures for a multicylinder engine?
11. Explain how to make a quick check of the ignition system.
12. How can you make a quick check of the fuel system to find out if fuel is getting into the cylinder?
13. What is the common reason that a two-cycle engine might run but lack power?
14. What is engine surging?

SELF PROJECT

Locate a small engine that will not run or that has signs of engine trouble when running. Make the quick troubleshooting checks described in this chapter. Here's how. (Follow all safety precautions.)

Turn to the engine troubleshooting chart in the chapter and study each item. After each "Complaint" listed in the chart, there is a list of things that could be the "Possible Cause." Compare each of the possible causes to the condition of the engine that you are diagnosing. If the possible cause does not apply, then read the "Check or Correction" for it and go on to the next "Possible Cause."

When you reach a "Complaint" that applies to the engine you are diagnosing, then check out each "Possible Cause" carefully by making the "Check or Correction" for it. By the time you finish working through the Engine Troubleshooting Chart, you will either have corrected the problem or have closely identified it.

30
Chapter

Operating and Maintaining Small Engines

After studying this chapter, you should be able to:

1. **Demonstrate how to start, operate, and stop a small engine**
2. **List the daily or regular maintenance procedures to be performed by the operator of a small engine**
3. **Explain how to clean a small engine**
4. **Demonstrate how to clean carbon from the muffler and exhaust ports of a two-cycle engine**
5. **Demonstrate how to change the oil and oil filter in a small engine**
6. **Describe how to prepare a small engine for winter storage**
7. **List the steps in an engine tuneup**
8. **Demonstrate how to perform a tuneup on a small engine.**

○ 30-1 STARTING A SMALL ENGINE   If the engine uses a rope-wind starter, make sure the equipment is level. This reduces the possibility of tipping the equipment over when you pull the rope. You can guard against tipping it by putting one foot on the equipment. Figure 30-1 shows the correct way to start a lawn mower.

CAUTION: Never put your foot under the lawn mower where the rotating blade might hit it. You could be seriously injured. When working around any machinery, stay clear of moving parts!

Never start and operate the engine in a closed place, such as a garage with the doors closed. The engine can produce enough carbon monoxide in only three minutes to kill you!

If the equipment has brakes, apply them when starting the engine. If it has a clutch, disengage it if possible, so the machine will not move when the engine starts.

Many engines have a shut-off valve between the fuel tank and the carburetor as shown in Fig. 30-2. If the fuel has been turned off, turn it on again.

Close the choke valve or prime the engine. Chokes and primers are described in Chaps. 17 and 18. Some manufacturers recommend that you turn the engine over a few times with the ignition off to allow gasoline to get into the carburetor. Then, when you crank with the ignition on, the start will be easier and quicker.

On riding equipment, operate the controls from the driver's seat. Then, if anything goes wrong or the equipment suddenly takes off, you can quickly stop the engine. Never start an engine until you know how to stop it.

Adjust the throttle to the recommended opening for starting. Some engines have a single control for choke and throttle. One model of lawn mower with

FIG. 30-1 Make sure that the mower is level and that you have it under control by holding it or by having a foot on it before using the rope-wind starter.

this type of control is shown in Fig. 30-3. On these engines, move the lever to the choke position. Then, when the engine starts, move the lever back to the open-throttle position.

Turn on the ignition and crank the engine. If you are using a rope-wind or rope-rewind starter, pull the rope until the engine reaches the compression stroke (Fig. 30-4). Then rewind the rope so you can give it a good hard pull through the compression stroke.

CAUTION: When starting a chain saw, put it on the ground or brace it so it will not get out of control when you crank it. If you do not have full control, the saw could get away from you with disastrous results, such as a badly cut leg or arm.

If you are using an electric starter, close the starter switch and allow the engine to crank for up to 10 seconds. Figure 30-5 shows how to start an engine with an electric starter. Avoid long cranking periods, because they can damage the starter.

If the engine does not start right away, open the choke valve part way and try again. The engine may have flooded (taken in too much gasoline).

Once the engine has started, allow it to operate at a fast idle for a minute or two so that it has a chance to warm up. Never run a cold engine at high speed or try to take full power from it. Give it a chance to warm up first. As the engine warms up, gradually open the choke.

If you have trouble starting the engine, refer to the troubleshooting chart in Chap. 29.

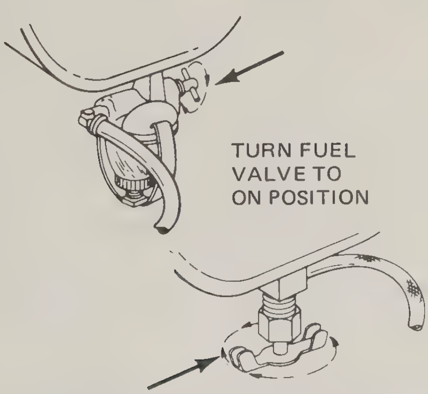


FIG. 30-2 To start the engine, first turn the fuel valve to the ON position. (*Kohler Company*)

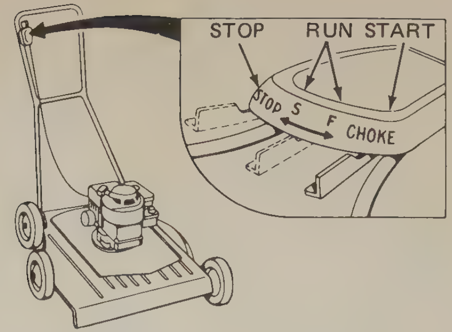


FIG. 30-3 Lawn mower with a single control lever. (*Briggs & Stratton Corporation*)

○ 30-2 OPERATING A SMALL ENGINE

Overloading and overspeeding are the two most common causes of small-engine trouble and short engine life. Overspeeding the engine by improperly adjusting the governor will shorten engine life and can actually cause the engine to blow up from the excessive speed. Also, high speed can spin the operating parts of the equipment faster than designed speed, with very damaging results. For example, rotation of the tips of the lawn-mower blades should never exceed a speed of 19,000 feet [5701 m] per minute. Manufacturers design their equipment to hold engine speed down so that this upper limit is never exceeded. If the engine is overspeeded sufficiently, the blade might explode. Parts would fly off and could seriously injure someone.

Overloading an engine can cause the engine to overheat so that engine parts will wear rapidly. If you have to use a mower under heavy load, such as cutting tall, wet grass, take it easy. Cut a narrow swath, and move the mower slowly.

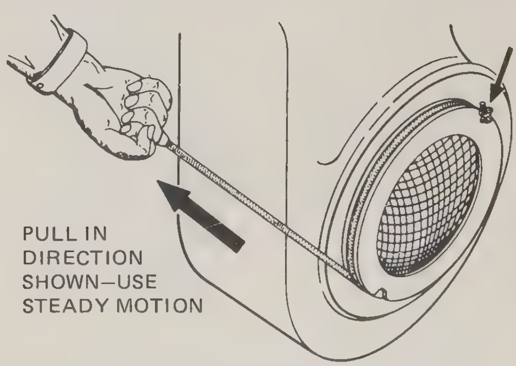


FIG. 30-4 To crank an engine with a rope-wind or rope-rewind starter, pull the rope until the engine reaches a compression stroke. Then rewind the rope. (*Kohler Company*)

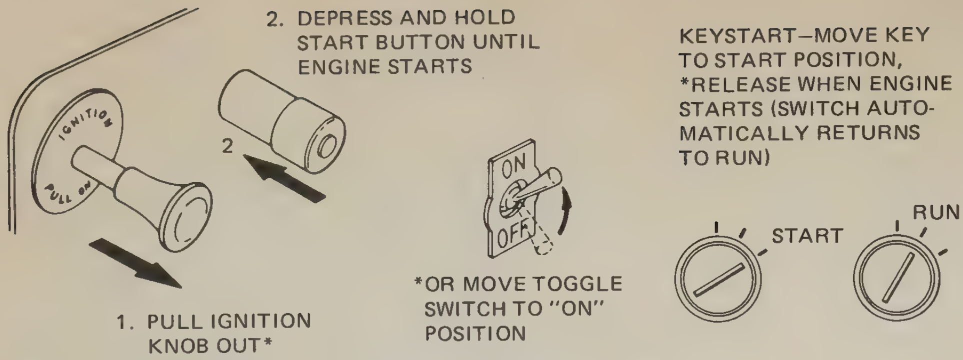


FIG. 30-5 Procedures for starting an engine with an electric starter. (*Kohler Company*)

If the engine is new or has just been rebuilt, allow it to work up to its maximum power gradually. On two-cycle engines, adjust the carburetor for a slightly rich mixture for the first 10 hours. On four-cycle engines, adjust the throttle to medium speed and allow the engine to run for about 30 minutes without load. Change the oil on four-cycle engines after the first five hours of operation. Follow the instructions on the nameplate attached to the engine or equipment. One manufacturer recommends that in overhauled engines having new blocks, nondetergent oil should be used as a break-in oil during the first five hours of engine operation. Then the nondetergent oil should be drained and replaced with SC oil of the proper viscosity. The brief use of nondetergent oil helps seat new piston rings in these engines.

CAUTION: Before working on the "business" side of power equipment, such as under the mower where the blade is or around the chain on the chain saw, always make sure the engine cannot start. Turn the engine off and disconnect the spark plug.

○ 30-3 STOPPING A SMALL ENGINE Although you might think there is nothing special about stopping an engine, there are actually right and wrong ways to do this. First, remove any load from the engine before turning it off. Then reduce engine speed to idle, and allow the engine to run for about a minute. This cools the engine down gradually and reduces thermal stresses on engine parts. Then shut off the engine. This may be done by shorting out the spark plug with a grounding blade or by returning the ignition-key switch or toggle switch to the OFF position as shown in Fig. 30-6. If the engine continues to run, or "diesels," after the ignition is turned off, stop the engine by closing the choke and opening the throttle wide-open.

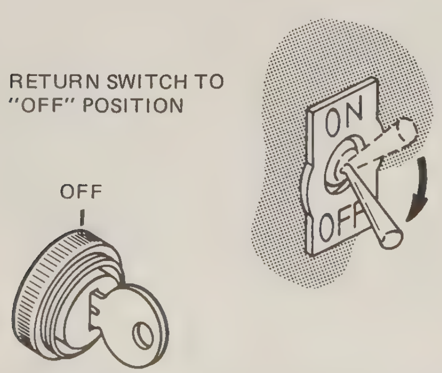


FIG. 30-6 Stop the engine by returning the ignition-key switch or toggle switch to the OFF position. (*Kohler Company*)

After turning the engine off, close the fuel-tank shut-off valve if the engine has one. This takes any pressure off the carburetor diaphragms or float and prevents fuel leaks.

If the engine will not be used for up to a month, drain the fuel tank and carburetor to prevent formation of gum which could clog carburetor passages. If the engine will not be used for a longer time, treat it as explained in ○ 30-14, which concerns winter storage.

○ 30-4 MAINTENANCE PROCEDURES This part of the chapter covers the maintenance procedures for small engines and explains how proper maintenance prolongs the life of engines. We have already examined common small-engine abuses that shorten engine life. Now we will look at the maintenance procedures that will help to ensure good engine performance and long engine life. This part of the chapter covers the kinds of small engines used in lawn mowers, edgers, and other similar applications.

Below is a list of the routine maintenance steps for small engines. In other sections, we explain how to perform these maintenance steps, such as cleaning the air cleaner and cleaning the engine.

Cleaning the Air Cleaner Clean and re-oil the air filter regularly. You will usually find instructions on the engine on when and how to do this job. The procedure for cleaning various types of air cleaners is covered in Chap. 18.

Tightening Fasteners Check the tightness of all bolts and nuts on the engine periodically. They sometimes

loosen up in service. If loose fasteners are not retightened, parts may become damaged or lost.

Lubrication Lubricate all bearings outside the engine, such as the wheel bearings on a power mower. Make sure oil reservoirs are filled, for example, on the chain saw lubricator.

Blades and Saw Teeth Make sure that the blades or saw teeth are sharp and that the rest of the assembly is in good condition.

Fuel Tank Keep the fuel tank filled. If it is allowed to sit around only partly filled, air will enter and leave the tank as the temperature changes. This will introduce moisture into the tank. The moisture will condense and will ultimately cause severe rusting of the metal tank. Rusting will damage the tank and lead to rust particles that get into the carburetor and clog the fuel passages.

Keep the Machine Clean Wipe off the machine periodically to remove oil, grass clippings, dust, and mud. Foreign matter that collects around the engine will act as a blanket and cause the engine to overheat. On mowers, clean off the accumulations of grass clippings from the inside of the housing. A later section describes in detail how to clean engines.

CAUTION: Be sure the engine switch (if used) is turned off and the spark plug high-voltage lead is disconnected so the engine will not start when you work on the "business" end of any machine. If a rotary mower should start while you are working on the underside, you could be seriously injured.

Many of the maintenance procedures described here should be performed periodically by the owner or operator of the engine. However, the engine does not always get the maintenance it should, with the result that its life is shortened. One of the most important services is to clean the engine and its components, such as the shroud, carburetor air cleaner, fuel strainer, and crankcase breather. It is dirt more than anything else that shortens engine life.

○ 30-5 CLEANING THE ENGINE Most small engines are air-cooled and have a cylinder with a series of cooling fins. These fins provide large surface areas from which the heat can be removed. The heat flows from the inside of the cylinder, through the cylinder metal, to the fins which dissipate it to the outside air. If these fins become dirty or covered with dirt and grass clippings, the heat cannot get through. The accumulations act as a blanket to hold heat in the engine. As a result, the engine becomes overheated. The oil film on the engine parts then becomes less effective, or actually fails, with the result that engine parts wear rapidly and engine life is shortened. For long engine life, clean a dirty engine before starting it.

Another purpose of periodically cleaning the engine is to check for loose nuts or bolts, and loose, broken, cracked, or otherwise damaged parts. A simple way to clean the engine is to use a stiff brush, soap or household detergent, and water. A brush will get into all the crevices where dirt can accumulate, and it will clean away most of the grass clippings and other trash that can cause trouble. For a complete cleaning job, use a degreasing compound, as explained later.

Parts to be cleaned include the shroud (on engines that have one), muffler and exhaust ports (on two-cycle engines), air cleaner, fuel strainer, and crankcase breather (on four-cycle engines).

Cleaning the Shroud Many small engines have fans and shrouds to direct the flow of air around the engine cylinder, as shown in Fig. 30-7. The blower housing, or shroud, will have to be removed before the engine can be thoroughly cleaned. Shrouds are held in place by screws which can be taken out to allow the shroud parts to be lifted off.

On some engines, you must remove certain other parts before the shroud can be removed. These parts might include the air cleaner, muffler, spark-plug wire, governor spring, or some other part.

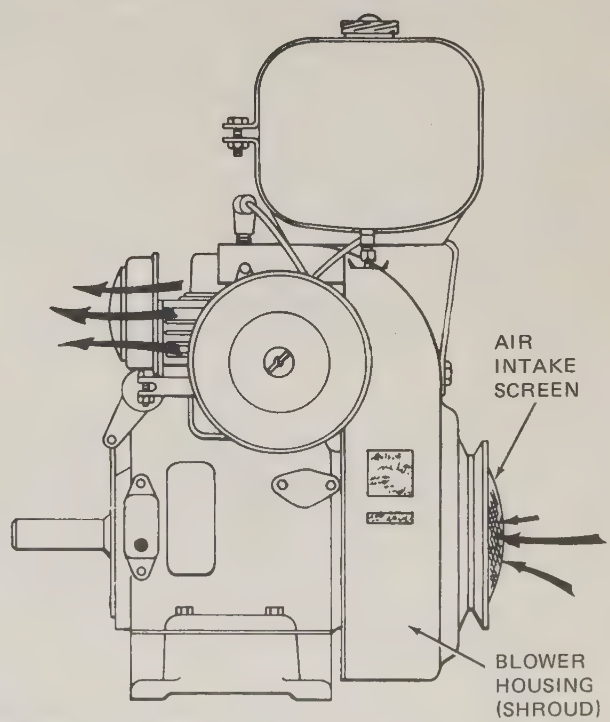


FIG. 30-7 The blower housing must be removed and cleaned periodically. (*Kohler Company*)

CAUTION: Never operate the engine with the shroud and baffles removed! The shroud is there to direct cooling air over the engine. When the shroud is off, the engine will overheat if operated. In addition, engines which have air-vane governors that operate on air flow will not function properly with the shroud off. The engine can overspeed and possibly destroy itself.

If the shroud is bent or damaged, it should be straightened, repaired, or replaced. A defective shroud can cause engine overheating. Also, it might interfere with the fan or other moving part.

If the shroud is dirty and has accumulations of grass clippings or other trash, scrape them off with a putty knife or similar tool. Use a stiff-bristled brush and solvent if necessary. Clean the air-intake screen with a brush and solvent if necessary. Get rid of all accumulations of trash that could prevent normal air flow through it.

Cleaning the Cylinder and Cylinder Head The fins on the cylinder and cylinder head should be cleaned to permit maximum heat transfer from the engine to the surrounding air. Three substances for cleaning the cylinder and head can be used: a degreaser, a solvent, and live steam. As a first step, use a wooden stick to scrape away all the accumulated trash and dirt. Do not use a metal tool, because it will scratch the cylinder and head and encourage accumulations of dirt.

Then use the material you have on hand to finish the cleaning job. Degreasing compound comes in pressure-spray cans or in larger containers. Solvent can be purchased from some service stations and from some auto-parts stores. To use live steam, you need a steam generator.

While cleaning the cylinder and head, check for oil leaks, which usually show up as a heavy accumulation of dirt. Check also for cracks or other damage.

Apply the solvent on the areas to be cleaned. The degreaser in the pressure can is easy to use on very small jobs. Other types can be applied with a bristle brush. After about five minutes, flush off the solution with a stream of water from a hose.

CAUTION: Do not clean a hot engine. Allow it to cool first. Cold water or other liquid on the hot engine can cause the head or cylinder to crack. Some cleaning solutions are flammable and could burst into flames if sprayed on a hot engine. Also, make sure that there is adequate ventilation. Some fumes from cleaning solutions are unhealthy to breathe.

○ 30-6 CLEANING THE MUFFLER AND EXHAUST PORTS On two-cycle engines, the exhaust ports tend to become clogged with carbon accumulations,

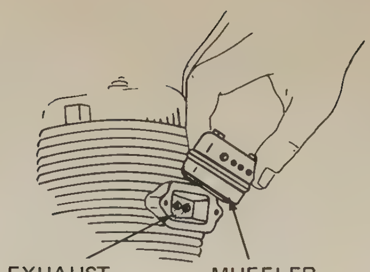


FIG. 30-8 Removal of muffler to inspect exhaust ports of a two-cycle engine.

as shown in Fig. 29-7. These accumulations reduce the ability of the engine to exhaust and can sharply reduce engine power. They can cause engine overheating, which will result in other engine damage. To check for carbon accumulations, remove the muffler, as shown in Fig. 30-8. Mufflers are made in a variety of sizes and shapes. They screw into the cylinder or are held in place by cap screws and a gasket. Removing the muffler permits you to inspect the exhaust ports.

If the ports are clogged, rotate the crankshaft until the piston moves down enough to cover the exhaust ports. This protects the engine from dirt and carbon which could otherwise fall into the engine and cause damage. Use a wooden stick to scrape off the carbon, as shown in Fig. 29-8. Do not use a metal tool that could scratch the piston or damage the edges of the exhaust ports. Hold the engine so that the exhaust ports are pointing down while you are scraping. This allows the loosened carbon to fall out and reduces the chances that any of it might get into the engine. To finish the job, blow out the ports with compressed air or use a brush to make sure you have removed all the carbon. Clean the muffler in solvent. When replacing the muffler, use a new gasket if the old one appears damaged. Tighten the attaching screws securely.

○ 30-7 SERVICING THE CARBURETOR AIR CLEANER The three types of carburetor air cleaners for small engines are oil-bath, oiled-filter, and dry-filter.

Regardless of the type of air cleaner, the usual recommendation is that the air cleaner be serviced after every 25 hours of operation under ideal conditions. If the engine is operated under extremely dirty or dusty conditions, then the air cleaner should be serviced much more often—as many as two or three times a day! Procedures for cleaning the three types of air cleaners are covered in Chap. 18.

○ 30-8 CLEANING THE FUEL STRAINER OR FILTER There are three general types of fuel strainers and fuel filters. They are the sediment-bowl type, the type mounted in the fuel tank, and the type having a weighted strainer at the end of a flexible hose. Ser-

vice of fuel filters and strainers is covered in Chap. 18.

○ 30-9 CLEANING CRANKCASE BREATHERS Four-cycle engines must have some means of allowing blow-by to escape. Blow-by is the seepage of unburned air-fuel mixture and combustion gases from the combustion chamber past the piston and rings. Pressure can build up in the crankcase if the blow-by has no way to escape, and this can damage the engine. Blow-by gases also can cause corrosion of engine parts and shorten engine life. Cleaning of crankcase breathers is covered in Chap. 18.

○ 30-10 SERVICING PCV VALVES In some older four-cycle engines, the crankcase was ventilated by an open oil-filter cap and a vent tube from the crankcase. The rotation of the crankshaft moved air through the crankcase. The air passing through removed the water, fuel vapors, and blow-by. However, the discharge of these gases into the atmosphere produced air pollution.

To prevent atmospheric pollution, many of these engines now have a closed system, called a positive crankcase-ventilation (PCV) system. Filtered air from the carburetor air cleaner is drawn through the crankcase. In the crankcase, the air picks up the water, fuel vapors, and blow-by. The air then flows back to the intake port and enters the cylinder. There the unburned fuel is burned.

The amount of air flowing through the crankcase must be controlled. Too much fresh air flowing through the intake port during idling would upset the air-fuel ratio. This could cause poor idling. To prevent this, a regulator valve is used. The valve is called a positive crankcase-ventilation (PCV) valve. Sometimes it is also called a crankcase emission-control valve. The PCV valve allows only a small amount of air to flow through during idle. But as engine speed increases, reduced intake vacuum allows the valve to open more. This, in turn, allows more air to flow through.

The PCV valve should be checked periodically. It should be replaced at regular intervals. Figure 30-9 shows the PCV valve in disassembled view. One manufacturer recommends that the PCV valve should be removed and cleaned at least every six months or after every 1200 hours of engine running time.

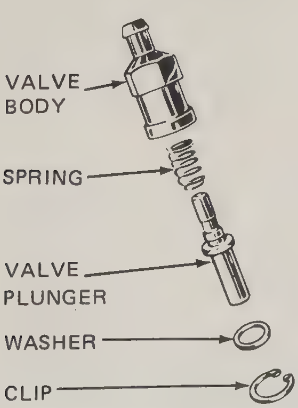


FIG. 30-9 A disassembled view of a PCV valve.

○ 30-11 CHANGING OIL AND OIL-FILTERS IN FOUR-CYCLE ENGINES Oil level in the crankcase of four-cycle engines should be checked after every few hours of engine operation. Some engines have a dipstick, which is attached to the filler plug or cap. On these, the dipstick should be removed, wiped, reinserted, and removed again, and the level of the oil on the dipstick noted. On other engines, the oil level in the crankcase is correct if the oil is filled to overflowing when the engine is level. Changing oil and oil filters is covered in detail in Chap. 15.

○ 30-12 LUBRICATING TWO-CYCLE ENGINES Lubrication of many two-cycle small engines is provided by adding oil in the recommended amount to the fuel. The fuel-oil mixture enters the crankcase in vapor form and passes on to the combustion chamber with the air-fuel mixture. Part of the oil, in mist form, is retained in the crankcase. There the oil lubricates the piston, rings, and crankshaft bearings. Some of the oil gets into the combustion chamber, where the oil is burned along with the air-fuel mixture.

The amount of oil to be mixed with the fuel is critical, and the manufacturer's recommendations should be carefully followed. Adding too much oil will cause the exhaust ports to become clogged very quickly, and carbon deposits will form on the piston and rings. This causes poor engine performance. Adding too little oil will deprive the engine of adequate lubrication, and so it will wear out sooner.

There is a wide range of fuel-oil mix ratios. A variety of ratios are required because the designs and clearances of two-cycle engines vary, just as their applications vary. Some engines require more oil than others. For example, in outboard engines, one manufacturer recommends a fuel-oil ratio of 50 : 1, while another recommends 32 : 1. A chain-saw manufacturer specifies a mix ratio of 40 : 1, and a motorcycle manufacturer wants 28 : 1. Before mixing oil into the gasoline, always be sure that you know the mix ratio needed by the particular engine you are servicing. A fuel mixing table is printed on many two-cycle oil containers. Chapter 15 covers in detail the lubricating of two-cycle engines.

○ 30-13 STORING GASOLINE There are local and state laws about storing gasoline. These laws are for your own protection, and they should be carefully observed. A basic rule is to never store gasoline in a closed room, where gasoline vapors will accumulate. Explosions have resulted from storage of gasoline in a closed room in a container that was not tightly

sealed. The accumulating gasoline vapors can be ignited by a spark from turning a light switch on or off or by a spark caused by one metal object's striking another.

Gasoline that is stored for any length of time deteriorates. It often is called stale gasoline. The length of time that the gasoline stays good depends on its composition and the additives that have been put into it. This is the reason that any machine that is to be stored for any length of time should have its fuel tank and carburetor drained of all fuel. Otherwise, the stale gasoline can deposit gum and varnish on critical parts. For example, carburetor jets can become clogged. This will cause poor engine performance and require a complete carburetor overhaul to set things right again. For the same reason, you should not store gasoline in containers for long periods and then use it.

○ 30-14 WINTER STORAGE For winter storage, drain the fuel tank, and run the engine to use up the fuel in the carburetor. Fuel left in a carburetor may form gum that will clog fuel passages. Remove the spark plug, and squirt about a tablespoon of heavy engine oil into the combustion chamber. Turn the engine over a few times to distribute the oil over the engine parts. Install the spark plug. Cover the engine with plastic or canvas, and store the engine in a warm, dry place.

○ 30-15 SERVICE AND MAINTENANCE SCHEDULES Small engines are used for a variety of purposes and under great extremes of operating conditions. To help ensure that the engine will deliver the maximum power for its normal life, engine manufacturers provide a maintenance, or service, schedule for each of their engines. A typical service schedule for a two-cylinder four-cycle air-cooled engine is shown in Fig. 30-10. The purpose of the service schedule is to remind the operator that certain checks must be made every day before starting the engine and that others must be made after a certain number of hours of operation.

In addition to adding gasoline to the fuel tank, the oil level must be checked and the air-intake screen cleaned. Then after every day that the engine runs without stopping, or after every 25 hours of operation, certain types of air cleaners must be serviced. You can see in Fig. 30-10 that additional checks must be made after every 50, 100, and 500 hours of engine operation.

Figure 30-11 shows an engine maintenance chart prepared by a manufacturer of small engines for electric generating sets. Note that the service intervals are extended to 5000 hours. At that time the engine will need a complete overhaul. All manufacturers emphasize that the service intervals they suggest in their service and maintenance schedules are based on good, clean, engine operating conditions. Should the engine be used in the desert or on a construction project, then the items should be checked much more frequently.

○ 30-16 ENGINE TUNEUP Now we describe the procedure known as engine tuneup. Tuneup includes testing the various components and systems involved in engine operation. It also includes readjusting or replacing parts as required to restore engine performance. Sometimes during a tuneup, serious problems may be uncovered that will require major repair work. Other chapters describe the service jobs that may be performed on engines.

Engine tuneup means different things to different people. To some, it means a light once-over check of the engine that takes in only the obvious trouble spots. To others, it means using the proper test instruments to do a careful, complete analysis of all engine components and, in addition, adjusting everything to specifications and repairing or replacing all worn parts. The latter is the proper meaning of engine tuneup, and it is the procedure outlined below.

An engine tuneup follows a more or less set procedure. Many service technicians follow a standard procedure recommended by the engine manufacturers. By following a procedure, the technician is sure of not overlooking any part of the procedure. However, not all tuneup procedures are exactly the same because not all engines are the same. Different companies have different ideas about what should be done and the order in which it should be done. In addition, sometimes the tuneup procedure depends on the equipment available. If test instruments are not available, then the tuneup is performed differently.

The procedure that follows includes all essential checks and adjustments that several manufacturers recommend.

○ 30-17 STEPS IN ENGINE TUNEUP The tuneup procedure restores power and performance that have been lost through wear, corrosion, and deterioration of engine parts. These changes take place gradually in many parts during normal operation. The steps that follow are also part of a complete engine overhaul.

1. Remove the air cleaner and check its condition. Note whether it has been serviced regularly.
2. Check the oil level and the condition of the oil in the crankcase. Then drain the oil and remove the oil filter.
3. Remove the cap from the fuel tank and check for dirt and rust in the fuel tank. Drain the fuel tank and clean it, if necessary. Clean or replace the

SERVICE SCHEDULE

SERVICE AT INTERVALS INDICATED	DAILY (PRE-START)	EVERY 25 HOURS	EVERY 50 HOURS	EVERY 100 HOURS	EVERY 500 HOURS
CLEAN AIR INTAKE SCREEN	X				
CHECK OIL LEVEL	X				
REPLENISH FUEL SUPPLY	X				
SERVICE MULTI-PHASE AIR CLEANER		X			
SERVICE OIL BATH AIR CLEANER		X			
SERVICE DRY-TYPE AIR CLEANER			X		
CLEAN EXTERNAL SURFACES OF UNIT			X		
CHANGE LUBE OIL			X		
CHANGE LUBE OIL FILTER				X	
SERVICE FUEL FILTER				X	
SERVICE SPARK PLUGS				X	
REPLACE ELEMENT—DRY AIR CLEANER				X	
CHANGE OIL IN WET TYPE CLUTCH				X	
SERVICE CRANKCASE BREATHER					X
CHECK AND SERVICE BREAKER POINTS					X
CHECK IGNITION TIMING					X
CHECK VALVE—TAPPET CLEARANCE					X
CHECK CRANKCASE VACUUM					X
CHECK COMPRESSION					X
CHECK SPECIFIC GRAVITY—BATTERY					X
SERVICE DC GENERATOR					X
SERVICE STARTING MOTOR AND DRIVE					X
SERVICE CYLINDER HEADS					X

NOTE: Intervals stated are for good, clean operating conditions only—service items more frequently (even daily or twice daily) if extremely dusty or dirty conditions prevail.

FIG. 30-10 Service schedule for a two-cylinder four-cycle air-cooled engine. (*Kohler Company*)

fuel filter. Inspect the fuel lines, and if they are in good condition, clean them.

4. Remove the blower housing and clean it. Check the starter and starter clutch. Examine the condition of the rope, and check the rewind assembly.

5. Carefully clean the cooling fins on the cylinder and head. Then clean the entire engine.

6. Remove the spark plug. Note its condition. Check the cylinder compression by rocking the flywheel or using a compression gauge. Record the reading. If the compression reading is low, squirt about a tablespoon of engine oil through

SERVICE & PARTS REQUIRED	HOURS OF OPERATION																	
	100	200	300	400	500	600	700	800	900	1000	1500	2000	2500	3000	3500	4000	4500	5000
Oil change	×	×	×	×	×	×	×	×	×	×								
Clean and adjust spark plugs	×	×	×	×	×	×	×	×	×	×								
Service air cleaner	×	×	×	×	×	×	×	×	×	×								
Clean and lubricate governor linkage	×	×	×	×	×	×	×	×	×	×								
Clean crankcase breather	×	×	×	×	×	×	×	×	×	×								
Change oil filter (where applicable)		×		×		×		×		×								
Empty fuel sediment bowl		×		×		×		×		×								
Check ignition points		×		×		×		×		×								
Inspect commutator, brushes, slip rings					×					×	×	×	×	×	×	×	×	COMPLETE RECONDITIONING
Clean out carbon and lead deposits					×					×	×	×	×	×	×	×	×	
Check valve clearances										×		×		×		×		
Blow out generator										×		×		×		×		
Clean carburetor										×		×		×		×		
Remove and clean oil base										×		×		×		×		
Flush radiator										×		×		×		×		
Clean generator										×		×		×		×		
Replace fan belt										×		×		×		×		
Replace spark plugs	AS REQUIRED																	
Replace or grind valves	AS REQUIRED																	
Replace points	AS REQUIRED																	
Replace generator brushes	AS REQUIRED																	
Replace piston rings	AS REQUIRED																	

FIG. 30-11 Maintenance chart for a small engine used in electric generating set. (*Onan Corporation*)

the spark-plug hole. Recheck the compression. If the compression remains low, indicating either bad piston rings or valves, tell the owner the engine can not be tuned up without overhaul or repair.

7. Remove the carburetor. Disassemble it, and inspect it for worn or damaged parts. Wash the parts in solvent. Replace any worn or damaged parts, and then reassemble the carburetor. Follow the manufacturer's specifications and make the initial adjustments of the carburetor.

8. Inspect the intake manifold, crossover tube, and intake elbow. Tighten all nuts and bolts. Replace any gaskets that are leaking.

9. Check the governor blade, linkage, and spring for damage and wear. Check the adjustment of mechanical governors.

10. Remove the engine flywheel and inspect it for cracks (Fig. 30-12). Check the crankshaft oil seals for leakage on the flywheel side and on the power-takeoff side of the engine. Check the flywheel key for wear and tightness in the grooves.

11. Remove the cover from the ignition breaker box, and check for proper sealing. Dirt inside the box indicates seal leakage.

12. Inspect the condition, alignment, and gap of the breaker points. Replace, or clean, and ad-

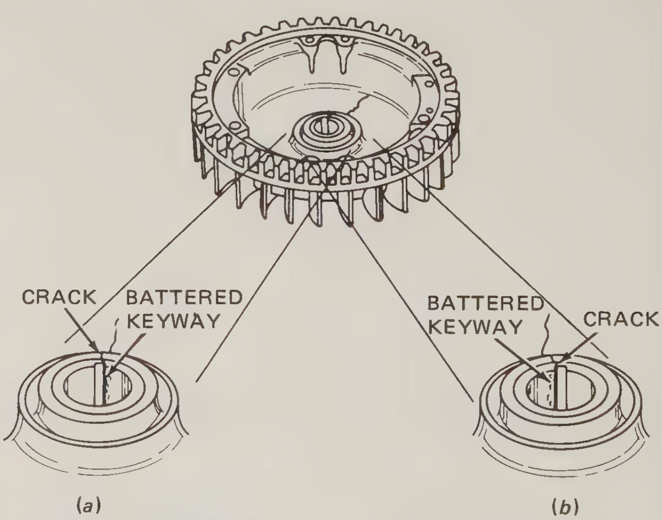


FIG. 30-12 (*a*) Flywheel cracked by sudden stopping of the crankshaft, such as by a rotary-mower blade striking a large rock. (*b*) Flywheel cracked as the result of being loose on the crankshaft. (*Tecumseh Products Company*)

just as necessary. Check the condenser, and the cam or plunger, that operates the breaker points.

13. Check the ignition coil for secure mounting, and check the wires connected to the coil for breaks and damaged insulation. Be sure none of the wires can touch the flywheel. Check the operation of the ignition stop switch, and its wiring.

14. Install the cover on the ignition breaker box. Use sealer to close the opening in the box through which the wires pass.

15. Install the flywheel. Time the engine, if necessary. Set the magneto armature air gap. Check the spark plug for sparks.

16. Remove the cylinder head. Check the gasket for signs of leakage. Clean carbon from the cylinder head, from the top of the piston, and from around the valves (four-cycle engines). Inspect the valves for proper seating.

17. Install the cylinder head. Torque it to specifications. Set the spark-plug gap and install the spark plug. Discard worn or defective spark plugs. Many shops install new plugs instead of servicing the old ones. Gap all plugs, old and new, before installing.

18. Remove the muffler, and check it for restrictions and damage. Clean or replace it, as necessary. Clean any carbon deposits from the exhaust ports.

REVIEW QUESTIONS

1. Why should you place your foot on a mower with a rope-wind starter before pulling the rope?
2. Should a chain saw be started while you are holding it in the air?
3. What are the two most common causes of short engine life?
4. What is the break-in procedure for a new or rebuilt engine?
5. Why should you always know how to stop an engine before you start it?
6. What effect will heavy layers of dirt and grass have on engine life?
7. How do you clean an air-cooled engine?
8. What is the danger in running an engine with the shroud off?
9. Describe the procedure to clean the carbon from clogged exhaust ports.
10. How often should the air cleaner be serviced under normal conditions?
11. Explain how to service the PCV valve.
12. How do you usually check the crankcase oil level in four-cycle engines?
13. What is stale gasoline?
14. Describe how to prepare a small engine for winter storage.
15. What is a maintenance schedule?
16. What is an engine tuneup?
17. When should a tuneup be performed?
18. What is the difference between engine troubleshooting and engine tuneup?

SELF PROJECT

To tune up an engine means to follow a logical procedure in performing a series of inspections, tests, checks, and adjustments. On a sheet of paper for your notebook, write down the most important steps in the tuneup procedure given in this chapter. Then add this page to your notebook. When you have an engine to tune, referring to your notebook will provide you with the key steps in the procedure.

31
Chapter

Servicing Two-Cycle Engines

After studying this chapter, you should be able to:

1. Demonstrate how to perform a top-end overhaul on a two-cycle engine
2. List the types of piston rings used in two-cycle engines
3. Demonstrate how to overhaul the bottom end of a two-cycle engine
4. Describe how to service the crankshaft bearings
5. Discuss when crankcase oil seals should be replaced
6. Describe how to break in a newly overhauled engine

TOP-END OVERHAUL

○ 31-1 STARTING THE JOB Before you begin any work on an engine, be sure you have a clean place to work, trays for the small parts you will remove, and the tools you will need. Most small-engine work can be done with a 3/8-inch drive socket set. This set includes the socket sizes most commonly needed for the job.

○ 31.2 REMOVING THE ENGINE If the engine is installed in a machine, you probably will need to remove it. There are exceptions. The engine in the minibike shown in Fig. 31-1 can have a top-end overhaul with the engine still in the frame. There is enough room above the engine to remove the head and cylinder without removing the engine itself. But if you do have to remove the engine from a lawn mower or other machine, detach all pulleys and adapters from the power-takeoff end of the engine. After the engine is removed, the next step is to clean it.

○ 31-3 CLEANING THE ENGINE Before starting to disassemble the engine, clean it thoroughly. Dirt is the greatest enemy of good engine-service work. Cleaning the outside of the engine is the best guarantee of not getting dirt inside the engine while you are working on it. Depending on how dirty the engine is, use a scraper, an old broom, or a stiff-bristle brush to knock off the larger chunks of dirt. Then brush off the remaining oil, dirt, and caked grease with chemical cleaner or with a strong mixture of detergent and water. Rinse off the outside of the engine with a hose, and allow it to dry. Some shops steam-clean engines before working on them. Be careful not to get water in the air cleaner, carburetor, muffler, or ignition.

○ 31-4 DISASSEMBLING THE TOP END Remove any shrouds or other parts that block access to the cylinder and head. Figure 31-2 shows removal of the

FIG. 31-1 Top-end service of this minibike does not require removal of the engine from the frame. (*Harley Davidson Motor Company*)

engine shroud, gasoline tank, and starter from the engine of a lawn mower. Next, disconnect the throttle and choke linkage, and remove the carburetor. Take off the exhaust pipe and muffler. Unscrew the spark plug.

Remove the screws or nuts holding the cylinder head and cylinder to the crankcase. Remove any other small parts as necessary. Remove the cylinder head. Pull the cylinder up about 2 inches [51 mm] away from the crankcase. Put a clean cloth or shop towel around the connecting rod and over the crankcase opening as shown in Fig. 31-3. This will help prevent any dirt from entering the crankcase as you remove the cylinder. However, if you are going to do a complete overhaul of the engine, it is not necessary to use the clean cloth to protect the crankcase as shown in Fig. 31-3. You will be disassembling and cleaning the crankcase components during the complete overhaul.

Now take the cylinder off the crankcase. Set the cylinder aside with the cylinder head end down on a clean piece of heavy cardboard. This protects it from damage to the crankcase sleeve or threads. With the cylinder removed, the piston- and connecting-rod assembly sticks up through the cylinder opening in the crankcase.

On some two-cycle engines, the head and cylinder are one piece (Fig. 31-4). To remove this type of cylinder assembly, unbolt it from the crankcase. Then pull the cylinder from the crankcase and off the piston. Use a cloth as shown in Fig. 31-3 before completing the removal if you are not going to service the crankcase end.

Now complete the disassembly of the top end by detaching the piston from the connecting rod. Pistons are attached in several ways in different engines. In one engine, the piston pin is a press fit in the rod. This type of piston pin must be pressed out in an arbor press or tapped out with a special punch. Other pistons are held in place by retaining rings (also called lock rings or Circlips). On these, use needle-nose pliers or a screwdriver, as shown in Fig. 31-5, to remove the rings. The pin can then be pushed out. With the piston pin out, the piston may be removed from the connecting rod.

○ 31.5 CLEANING THE ENGINE PARTS With the top end of the engine disassembled, clean the parts. This is necessary so that the parts can be checked, inspected, and measured. The job of cleaning top-end parts often is called decarboning the engine.

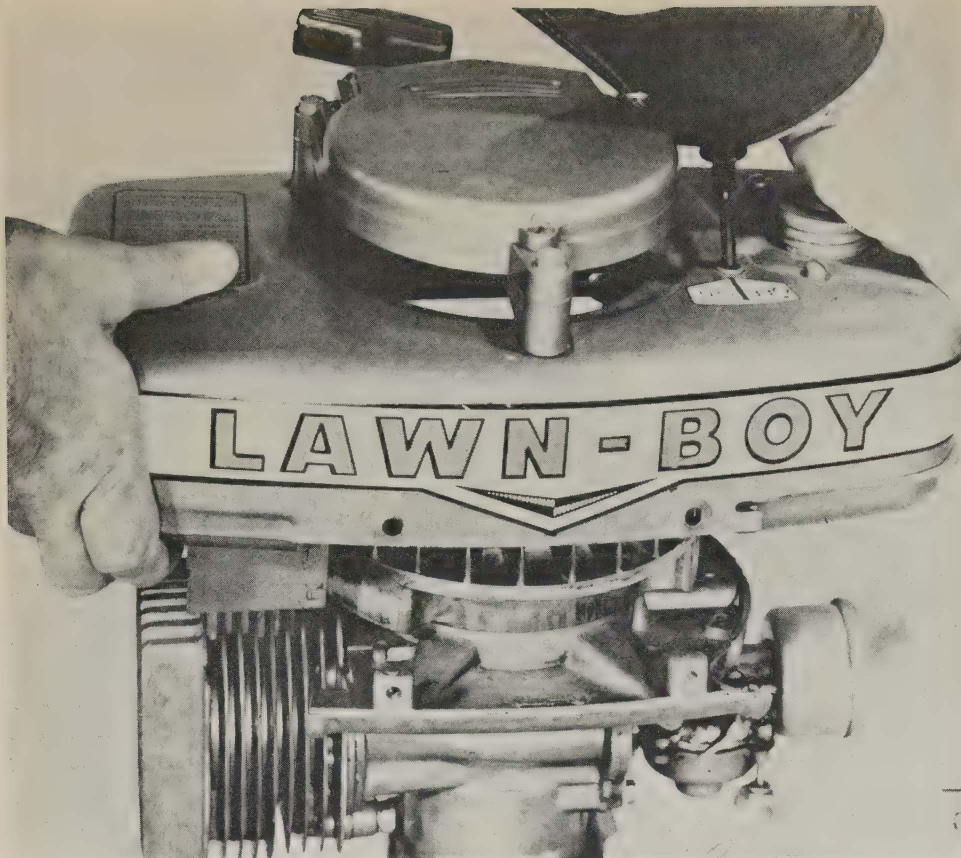


Fig. 31-2 Removing engine shroud, gasoline tank, and starter as an assembly. *(Lawn Boy Division Outboard Marine Corporation).*

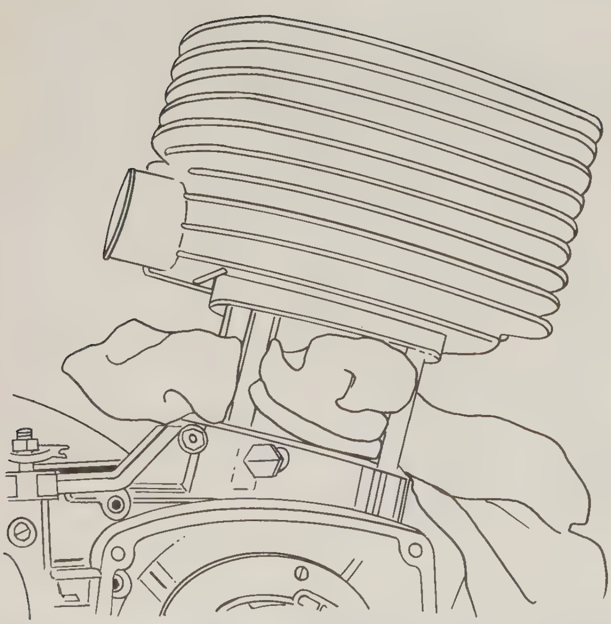


FIG. 31-3 Place a clean cloth around the connecting rod and the crankcase opening to prevent dirt from entering the crankcase.

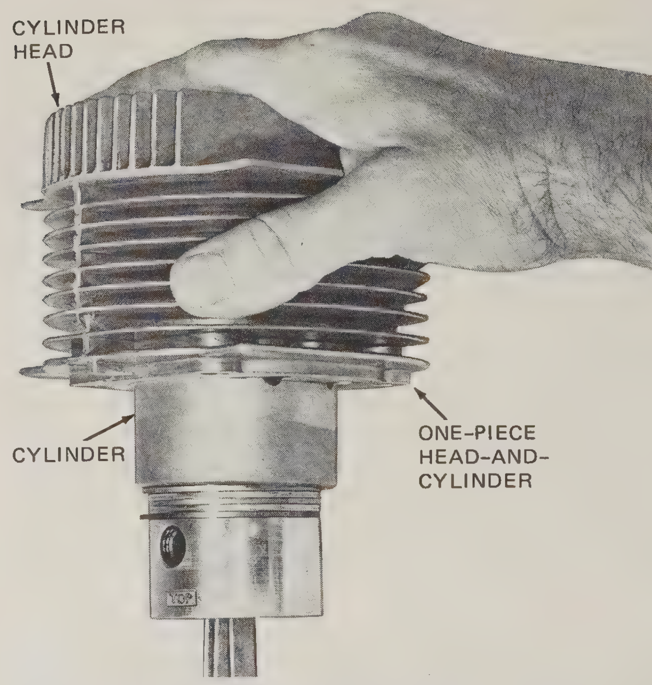


FIG. 31-4 Removing the one-piece type of cylinder-and-head assembly from the piston. (*Lawn Boy Division of Outboard Marine Corporation*)

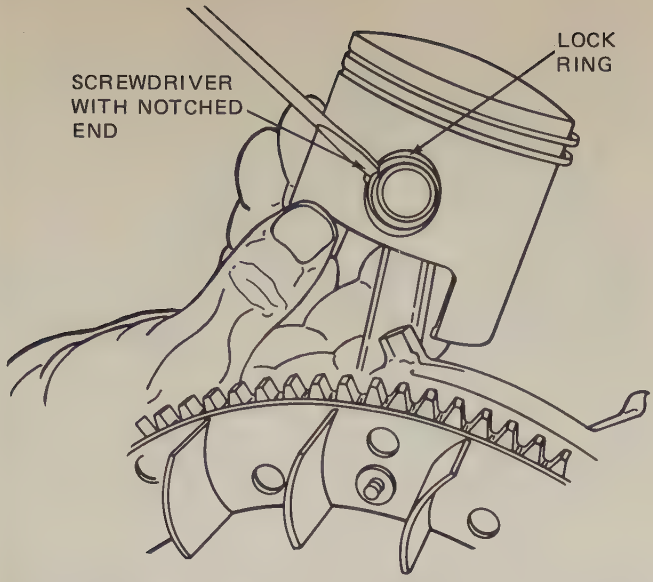


FIG. 31-5 Screwdriver with a notch ground in the end of the blade, used to remove piston-pin lock ring. (*Kohler Company*)

The two-cycle engine requires a mixture of oil and gasoline. Part of the oil burns away during the combustion process, but some of it becomes a hard carbon deposit. This deposit forms in the transfer port, exhaust ports, and exhaust passages, on the top of the piston, and on combustion chamber surfaces. The exhaust ports in the cylinder can become so clogged, as shown in Fig. 29-7, that the engine will barely run. To remove the carbon use a hardwood scraper to scrape away the accumulations as shown in Fig. 29-8. Very fine sandpaper can be used to finish removing any remaining carbon from the ports.

Removing the carbon from the exhaust ports can be done on an engine without disassembling it. To remove the deposits on an assembled engine, take off the exhaust muffler. Then turn the crankshaft so that the piston covers the exhaust ports. Use the scraper to remove the carbon, as described above. The piston will keep carbon particles from falling into the cylinder where they could cause trouble. Be very careful to avoid scratching the piston. Blow out all loose particles from the ports.

Remove the old gasket from the cylinder head, if the head is detachable, and from the cylinder-to-crankcase surface. Clean any sticking gasket material from the metal surfaces. Wash all parts in clean solvent. Dry the parts with air or with a clean cloth. Take a look at the spark-plug threads. If you can see carbon deposits in the threads, clean them by running a 14-mm tap through the spark-plug hole.

○ 31-6 INSPECTING THE CYLINDER

As a first step in servicing the cylinder, clean it as previously explained. Then inspect it and do whatever refinishing is required.

Examine the cylinder for cracks, stripped threads in the bolt holes, broken fins, and scores or other damage in the cylinder bore. Any of these require replacement of the cylinder. Sometimes stripped threads can be repaired with a thread-repair kit as shown in Fig. 31-6. The repair is made by drilling out the damaged threads. Then the hole is tapped with a special tap that comes with the repair kit. Finally, a threaded insert is screwed into the hole to bring it back to its original thread size.

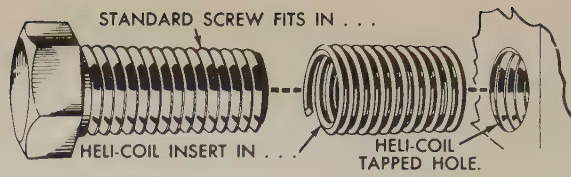


FIG. 31-6 Heli-Coil installation.

If the cylinder appears to be in good condition, use an inside micrometer or a cylinder bore gauge to

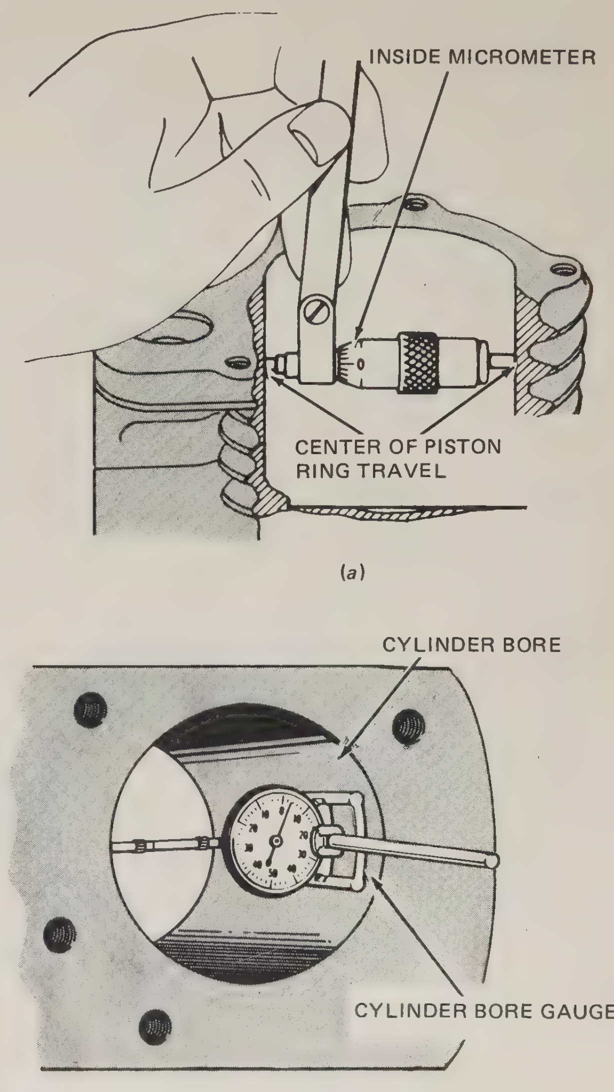


FIG. 31-7 Methods of measuring the cylinder bore. (*a*) Using an inside micrometer. (*b*) Using a cylinder bore gauge.

check the cylinder bore for wear, taper, and out-of-round (Fig. 31-7). A telescoping gauge and an outside micrometer can also be used to check the cylinder bore (Fig. 31-8). Take the measurements at several places to check for taper and out-of-round (Fig. 31-8). The difference between wear, taper, and out-of-round is shown in Fig. 31-9.

Some small engines have cylinders of aluminum with cast-iron liners (Fig. 31-10). The cast-iron liner is included to serve as the bore and wearing surface. Cast iron wears very little as compared with aluminum. When you find a cylinder of this type, check to see if the cast-iron liner has worked loose. A loose liner causes piston and cylinder overheating. The heat cannot escape easily if the liner is loose. If there are blue spots on the bore (from the cast-iron overheating) or if the liner is loose, discard the cylinder.

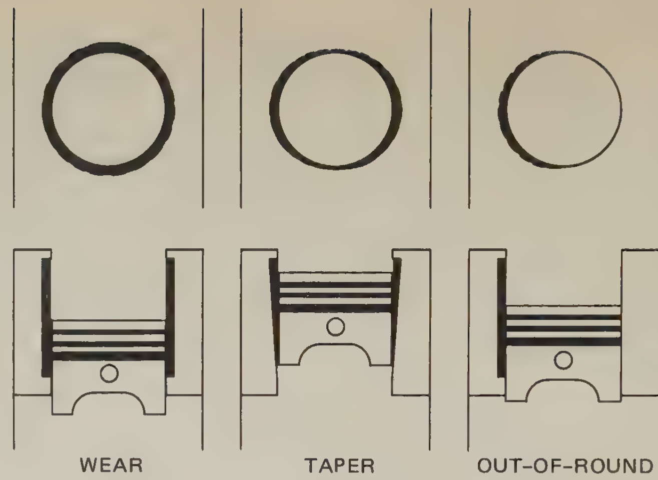


FIG. 31-9 Cylinder wear, taper, and out-of-round.

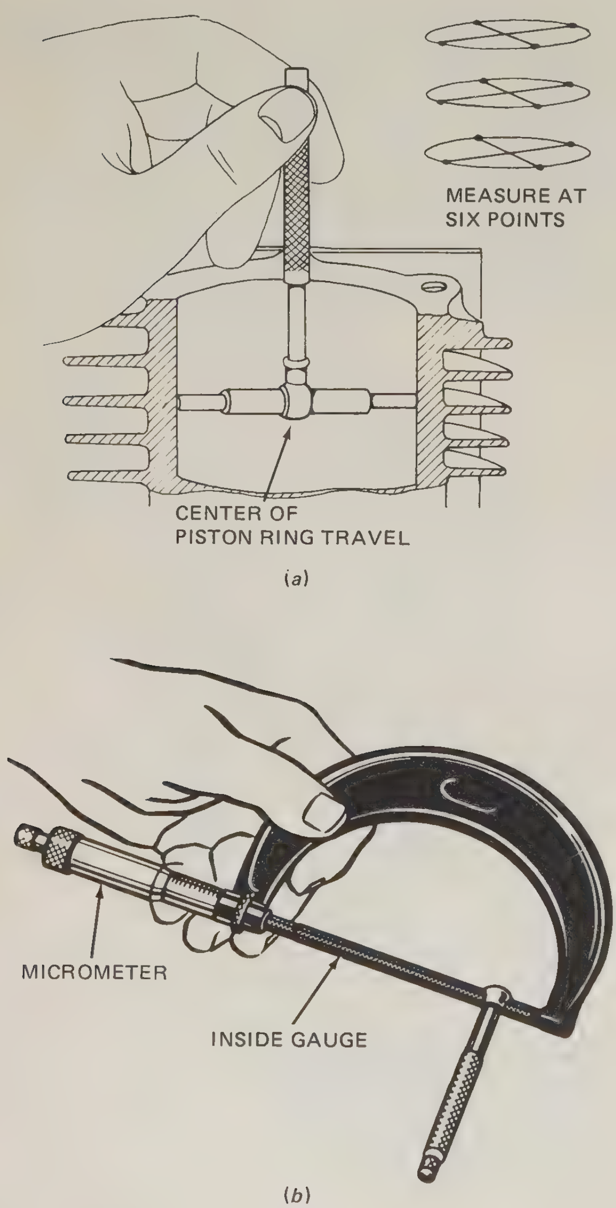


FIG. 31-8 Taking bore measurements with a telescoping gauge and an outside micrometer. First you set the gauge to the bore diameter (*a*), and then you determine the diameter by using the micrometer as shown at (*b*).

Other small engines have chrome-plated cylinder bores. Chrome is harder and wears less than cast iron. You can identify chrome-plated cylinders by their shiny appearance. These cylinders cannot be refinished. If they show signs of wear or scoring, replace the cylinder.

○ 31-7 REFINISHING THE CYLINDER If the cylinder is scored, worn, tapered, or out-of-round, it must be bored or honed to a larger size so that larger piston and rings can be installed. Pistons are supplied in standard oversizes, such as 0.010, 0.020, and 0.030 inch [0.25, 0.50, and 0.76 mm]. The cylinder, unless it is a chrome-plated cylinder, must be refinished to take one of these *standard oversize pistons*. Chrome-plated cylinders cannot be refinished.

Figure 31-11 shows the honing procedure for a cylinder of a one-cylinder two-cycle engine with a detachable cylinder head. The honing should be done from the crankcase end of the cylinder. Honing also is done in a drill press and in special shop hones that have fixtures for holding the cylinder. Follow the instructions supplied by the hone manufacturer for installation of the hone in the cylinder, operating speed, and lubrication. Remove the hone and *measure the cylinder periodically so you do not remove too much metal*. When the cylinder is approxi-

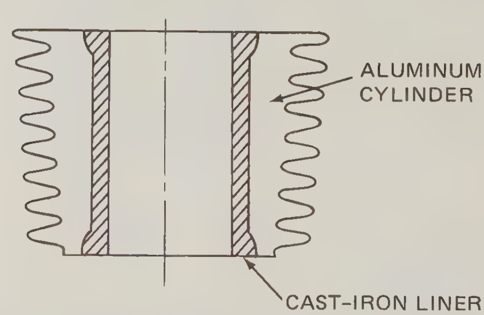


FIG. 31-10 Aluminum cylinder with a cast-iron liner.

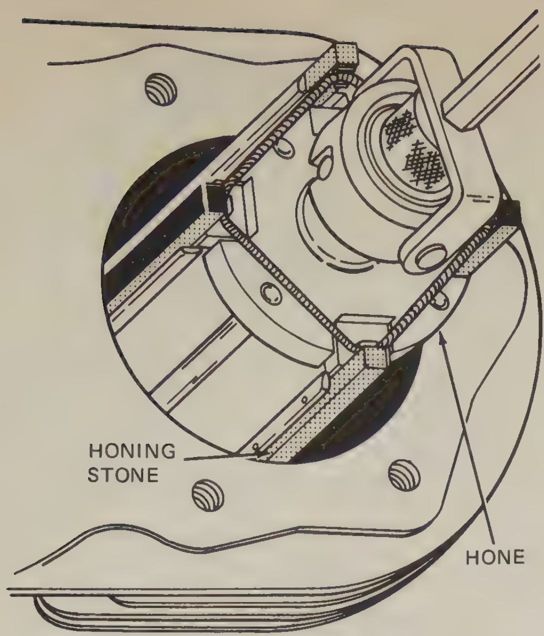


FIG. 31-11 Honing the cylinder of a two-cycle engine. (*Onan Corporation*)

mately 0.002 inch [0.05 mm] within the desired size, change to fine stones to finish the honing operation. Usually, rough honing is done with 60-grit stones. Finish honing is done with 220-grit stones. When the honing job is finished, the cylinder wall should have a *crosshatch pattern* such as shown in Fig. 31-12. This finish requires that the hone be moved up and down at the right speed while the hone is rotating at the proper speed.

A one-piece cylinder block-and-head assembly should be machine-bored and not honed when cylinder-bore oversizing is necessary. However, when cylinder oversizing is not necessary, use the hone to break the glaze on the cylinder wall. Roughen the cylinder wall slightly by running the hone through the cylinder several times. This will help new piston rings seat faster in a rebuilt engine.

CAUTION: The cylinder wall must be cleaned very carefully after honing. This is to remove all particles of grit and metal that may have become embedded in the cylinder wall.

The best way to clean the cylinder wall is to use soap and water and clean rags or a mop. Wash the cylinder wall thoroughly or until you can rub a clean cloth on it without getting the cloth dirty. Then dry the cylinder wall and coat it with engine oil. Do not use kerosene or gasoline to clean the cylinder wall. They will not remove all the grit.

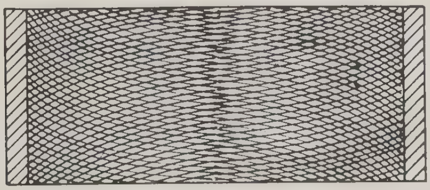


FIG. 31-12 Crosshatch appearance of a properly honed cylinder bore. (*Briggs & Stratton Corporation*)

○ 31-8 CLEANING AND SERVICING THE PISTON

Remove the piston rings one at a time. Use a ring expander to spread each ring so it can be slipped over the head of the piston as shown in Fig. 31-13. This avoids damaging the piston. Usually, new rings should be installed every time the engine is overhauled. The exception is if the rings have been used only a short time. In this case, the rings can be cleaned and inspected. If they are in good condition, they can be reinstalled.

If the cylinder wall is worn so that the cylinder requires refinishing, then both new rings and a new piston will be required, as explained previously.

Inspect the piston for scuffing and scoring, cracks in the head or skirt, and damaged or broken ring lands. A ring land is the metal ring between the ring grooves. Cracks or similar damage means the piston should be discarded. However, some pistons that have rough or lightly scored piston skirts can be repaired and reused. One repair method is to polish the piston with a soap-filled steel-wool pad. Then rinse the piston in running water, and when all soap and metal particles have been washed off, dry the piston and coat it with light engine oil. Another way to smooth up a rough piston skirt is to use an oil stone. Hold the piston in your hand and work the oil stone over the scuffed area, following the pattern shown in Fig. 31-14. If the damage does not clean up, discard the piston.

Check the piston dimensions with a micrometer as shown in Fig. 31-15. Compare these dimensions with the cylinder dimensions previously checked (Figs. 31-7 and 31-8). The difference is the piston clearance. Some engine manufacturers recommend checking the fit of the piston in the cylinder bore with a feeler

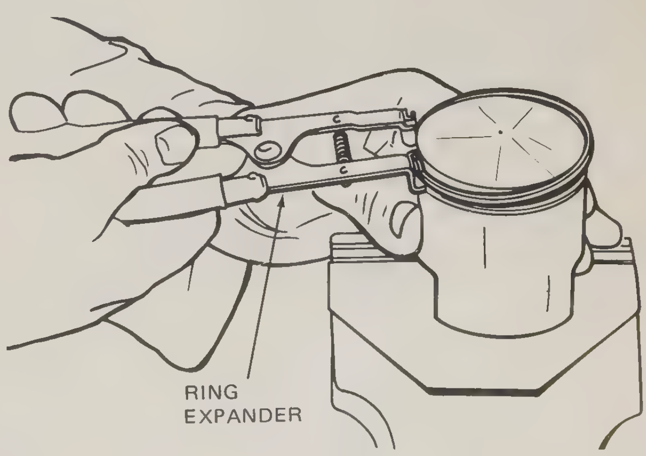


FIG. 31-13 Using a ring expander to remove the piston rings from the piston. (*Kohler Company*)

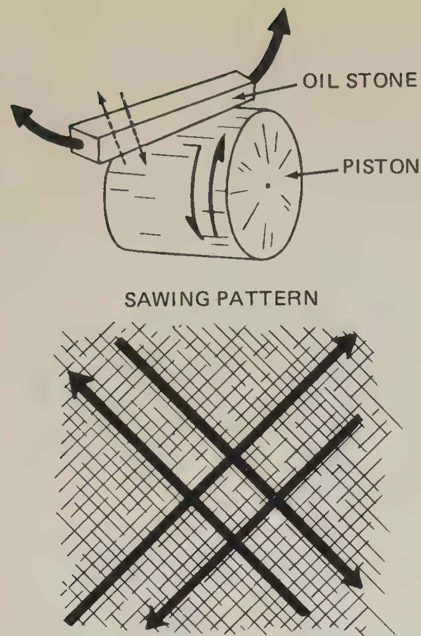


FIG. 31-14 Using an oil stone to clean up a scuffed piston. (*Yamaha Motor Company, Ltd.*)

gauge. The piston is inserted in the bore with the feeler gauge along its side (Fig. 31-16). If the piston moves too freely, the clearance is excessive. Too much clearance requires reboring the cylinder to a larger size and installing an oversize piston, as previously explained.

If the piston checks out properly so far, inspect the ring grooves. Clean out the carbon with a groove cleaner (Fig. 31-17) or with a piece of a broken piston ring. Do not remove metal; remove carbon only. It may help to soak the piston in old carburetor cleaner or a liquid chemical cleaner that is recommended for aluminum. Then scrape any remaining carbon from the grooves.

Never use a wire brush on a piston. The wire bristles will scratch the piston and can round off the outside edges of the piston-ring lands.

Next, check for ring-groove wear. Use the rings you are to install on the piston to make this check. First, roll the ring around the groove as shown in Fig. 31-18. The ring should roll freely in the groove all the way around. If it binds in any place, there probably is still some carbon in that spot, or there is a metal burr on the side of the piston-ring land. This must be removed. Another check for ring-groove wear is to use a feeler gauge to measure the clearance between the ring and ring land (Fig. 31-19).

If the ring grooves appear satisfactory, check the ring gaps with the rings in the cylinder as explained in ○ 31-9 and then install the rings, using the ring expander as shown in Fig. 31-13. In two-cycle engines, the piston rings are pinned so they cannot move around. Figure 31-20 shows several pinning methods. If the rings move around, their ends might catch in the transfer or exhaust ports. This could break the rings and piston.

After the rings are in place on the piston, attach the piston to the connecting rod and install the cylinder and cylinder head as explained in a following section.

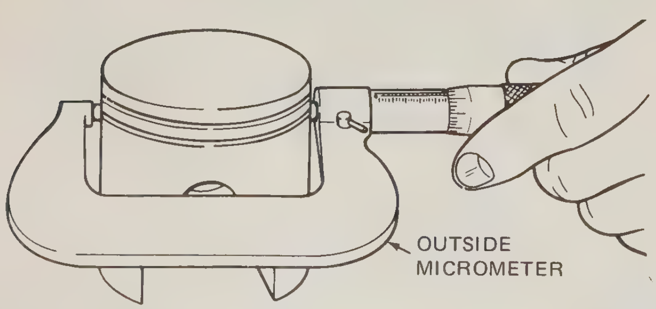


FIG. 31-15 Measure piston skirt just below bottom ring and at a right angle to the piston pin. (*Kohler Company*)

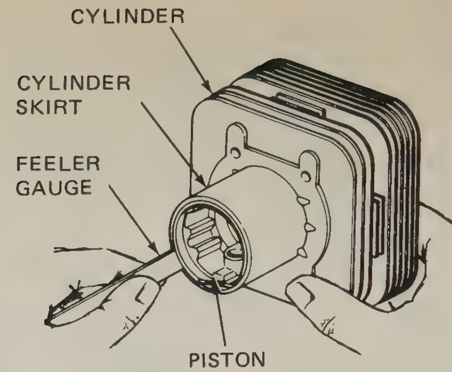


FIG. 31-16 Measuring piston clearance with a feeler gauge. (*Outboard Marine Corporation*)

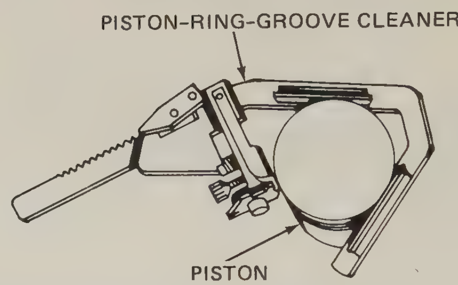


FIG. 31-17 Piston ring-groove cleaner.

FIG. 31-18 Checking the piston ring for tightness or binding by rolling it around the groove. (*Outboard Marine Corporation*)

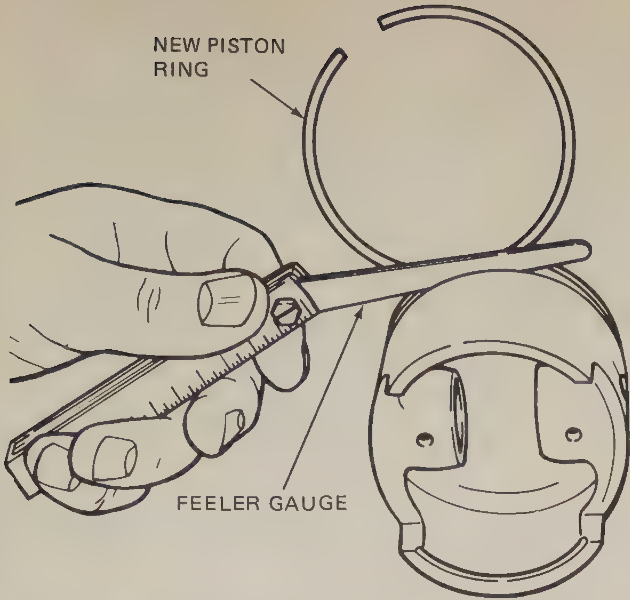


FIG. 31-19 Checking the side clearance of the piston ring in its groove. (*Kohler Company*)

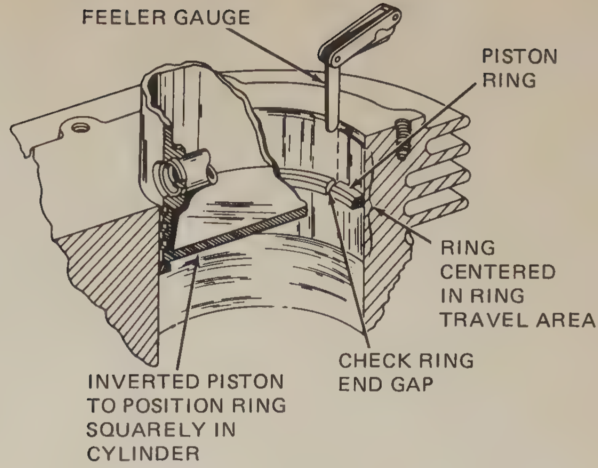


FIG. 31-21 Squaring ring in cylinder bore with a piston in preparation for measuring ring gap. (*Tecumseh Products Company*)

○ 31-9 PISTON-RING SERVICE As a rule, new piston rings should be installed every time an engine is disassembled for an overhaul. However, if the rings are relatively new, have been in use in the engine for only a short time, and are in good condition, they might be used again.

Before a piston ring is installed on a piston, the ring gap—the gap between the ends of the ring—must be checked. This is done by pushing the ring down in the cylinder with the piston turned upside down, as shown in Fig. 31-21. Measure the gap with a feeler gauge. If the gap is excessive, do not use the ring. If there is no gap, you have the wrong ring for the job.

○ 31-10 TYPES OF RINGS Many small engines use keystone rings (Fig. 31-22). The keystone piston

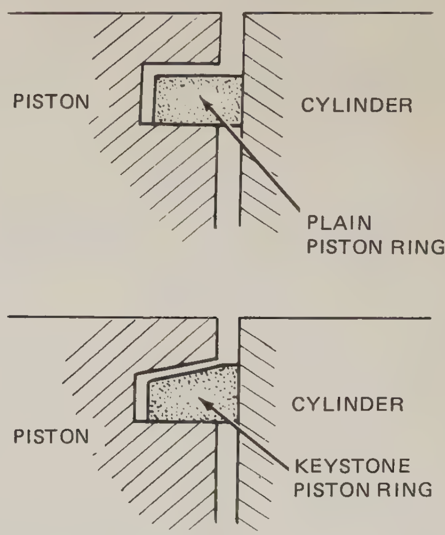


FIG. 31-22 Comparison of the regular or plain piston ring (top) with the keystone piston ring (bottom). (*Yamaha Motor Company, Ltd.*)

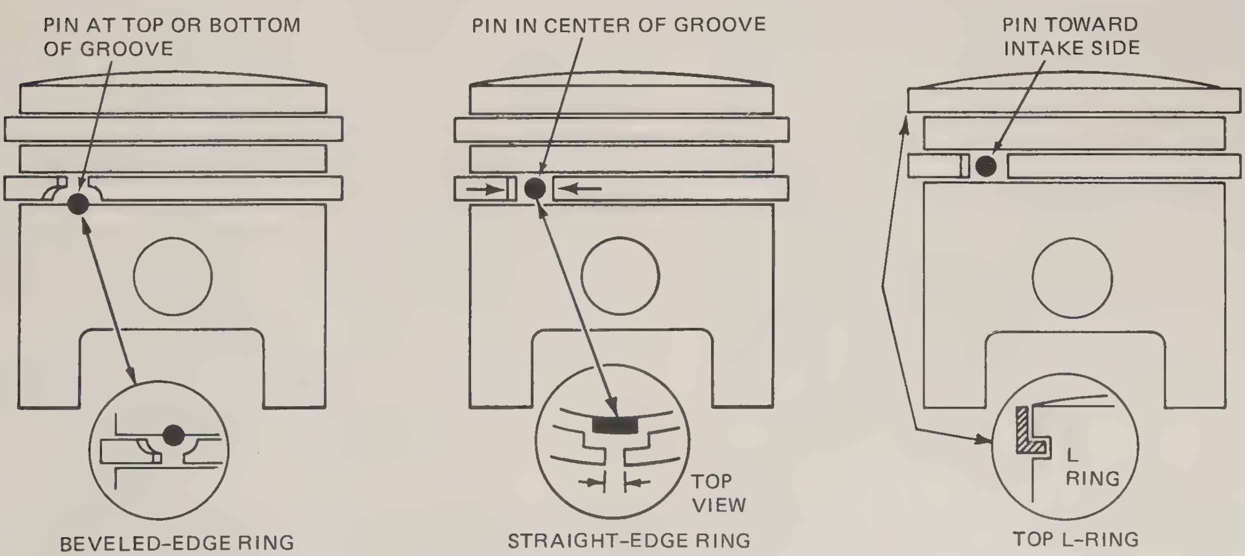
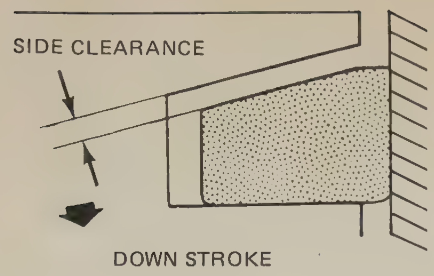


FIG. 31-20 Various pin-type piston rings used in small engines. (*Kohler Company*)



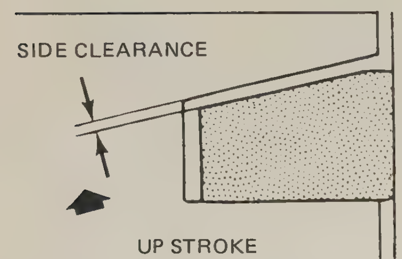


FIG. 31-23 The in-and-out movement of the keystone piston ring tends to make it self-cleaning.

ring tends to be self-cleaning, an especially important feature for two-cycle engines. These engines accumulate carbon in the cylinder, because some of the oil mixed with the gasoline burns. Figure 31-23 shows the self-cleaning action.

The keystone rings must not be installed upside down, because this would probably break them. Actually, the caution about not installing piston rings upside down applies to all rings. But it is especially important for keystone and L rings.

The top ring in some engines is L-shaped as shown in Fig. 31-20. This ring tends to reduce the amount of unburned air-fuel mixture that exits from the cylinder during exhaust. The reason is that there is no space between the top ring, cylinder wall, and top of the piston as there is in other ring designs. This space, in engines not using the L ring, contains unburned air-fuel mixture which cannot burn because it is next to the relatively cool metal. During exhaust, this unburned mixture mixes with the exhaust gas, increasing the amount of HC in the exhaust.

○ 31-11 CHECKING CONNECTING-ROD SMALL-END AND BIG-END BEARINGS The piston is attached to the connecting rod in a variety of ways. In some, the piston pin is a press fit in the connecting rod. In others, the pin is supported in the rod with a sleeve or roller bearing (Fig. 31-24). The fit of the pin to the bearing should be checked, and if it is not correct, a new bearing, or a new connecting rod, will be required. In some engines using sleeve bearings in the rod small end, it is possible to ream the bearing to a larger size and use a larger size pin. If this is done, the bearing surfaces in the piston must also be reamed to a larger size.

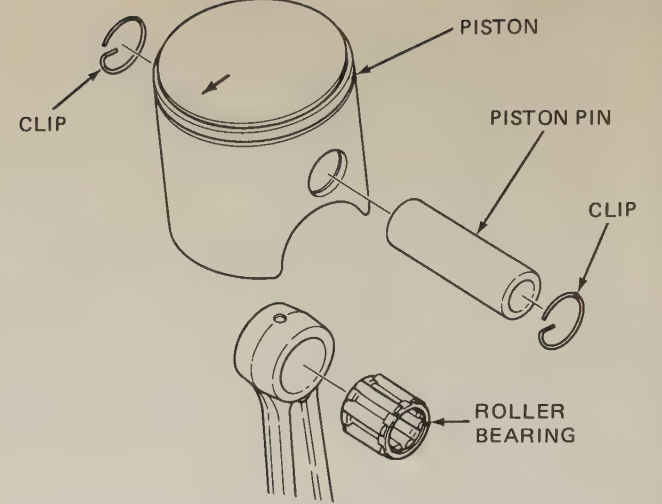


FIG. 31-24 Piston and connecting-rod assembly that uses a roller bearing in the small end of the connecting rod. (*Yamaha Motor Company, Ltd.*)

Before installing the cylinder or attaching the piston to the connecting rod, make the following check of the rod big-end bearing. Move the rod from one side to the other to see how much it will wobble (Fig. 31-28). If the rod small end can be moved more than a certain maximum, the rod big-end bearing is worn excessively. One manufacturer specifies that if the small end moves 0.080 inch [3 mm] or more, the big-end bearing requires service.

○ 31-12 INSTALLING THE PISTON After the rings are installed on the piston, attach the piston to the connecting rod with the piston pin. Coat the piston pin with oil before installing it. Some piston pins can be pushed in with a thumb. Others require a press or special tool (Figs. 31-25 and 31-26). If lock rings are used, install them. Then coat the cylinder and the piston and rings, and install the cylinder over the

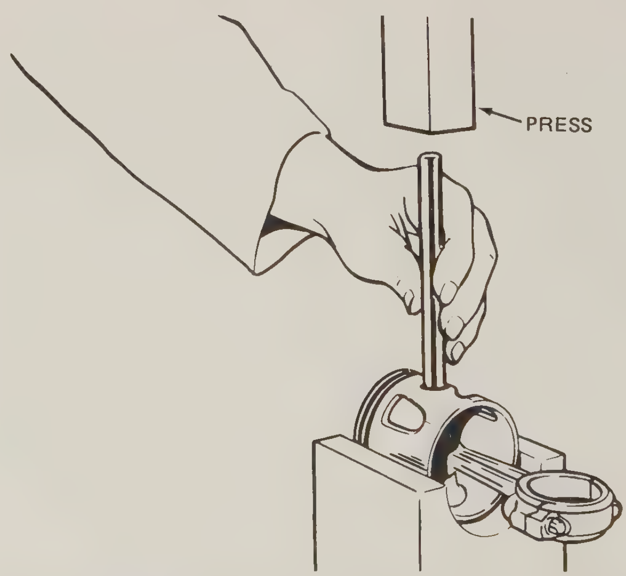


FIG. 31-25 Using a press to push the piston pin into place.

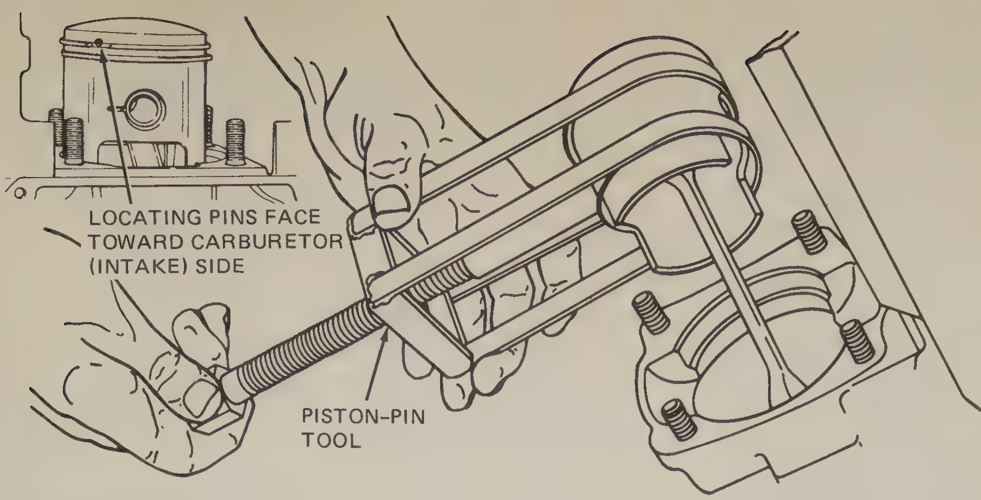


FIG. 31-26 Using a special piston-pin tool to install a piston pin. (*Kohler Company*)

piston and rings as explained in ○31-13. A ring compressor is required to compress the rings into their grooves so the cylinder can be slipped down over the piston. Figure 31-27 shows one type of ring compressor.

○31-13 INSTALLING THE CYLINDER Coat the cylinder bore with oil. Remove the cloth that you placed around the connecting rod to prevent dirt from entering the crankcase. Install a new cylinder base gasket on the through bolts, and slide the gasket into place on the crankcase. Place the cylinder over the through bolts. Slide the skirt of the cylinder over the head of the piston. Use your fingers or a hinged ring compressor to compress each ring into the cylinder. When all rings are in the cylinder, slide the cylinder into place in the crankcase.

If a separate cylinder head is used, place a new head gasket on the cylinder. Then properly position the head and set it in place. Reinstall the washers and nuts on the through-bolt threads. Turn the nuts until they are finger-tight. Then use a torque wrench to torque the nuts to the manufacturer's specifications. Be sure to follow the torquing sequence recommended by the manufacturer.

Install the carburetor, being careful not to overtighten the nuts that hold it in place. Overtightening might cause the base of the carburetor to break off. Reinstall the shrouding and all other parts removed when you began the top-end overhaul.

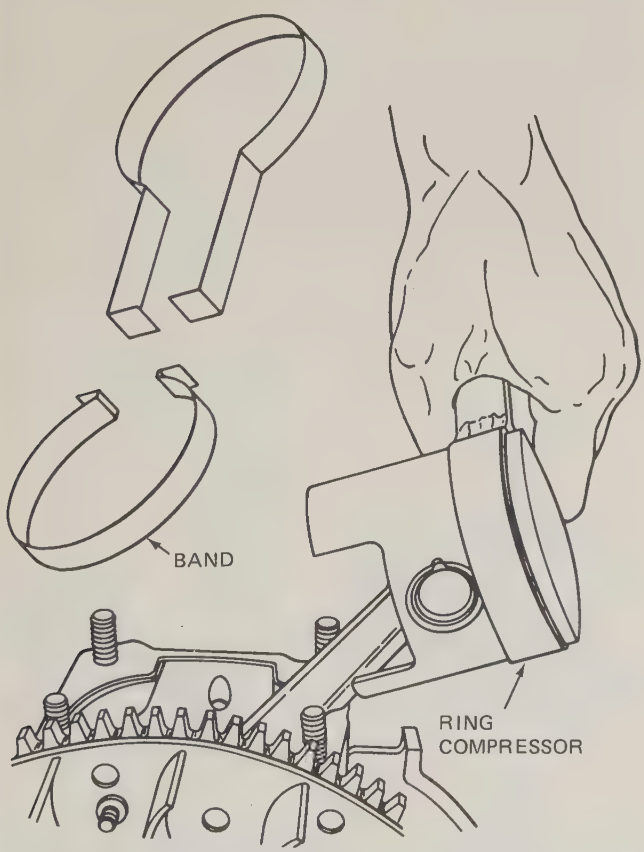


FIG. 31-27 A two-piece band-type ring compressor is used to install the piston on many two-cycle engines. (*Kohler Company*)

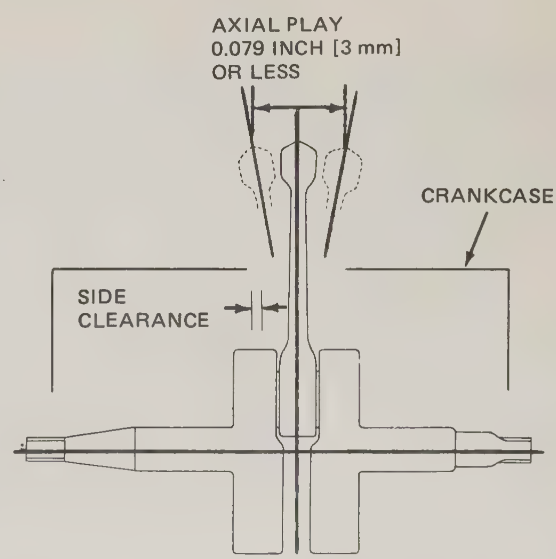


FIG. 31-28 Checking the condition of the big-end bearing by measuring the axial play in the connecting rod. (*Outboard Marine Corporation*)

Check that the engine has a supply of oil and gasoline mixed to the proper ratio in the fuel tank, or that the oil-injection oil tank is full. This assures ample lubrication during start-up. Then start the engine.

Some manufacturers indicate that no special break-in procedure is needed. In general, it is good practice to operate the engine for the first few times at light load to give the piston rings and other parts a chance to seat. After 10 hours of operation, no further break-in precautions are required.

A two-cycle engine that has been properly overhauled will give its owner hundreds of hours more of dependable service. In this part of the chapter, you learned how to thoroughly recondition the top-end of a two-cycle engine. This is one of the most common service jobs that these engines require.

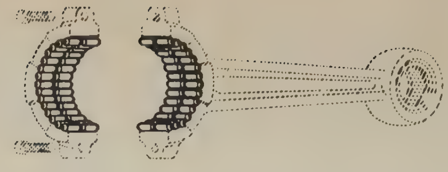
BOTTOM-END OVERHAUL

If a complete overhaul job is required, then the top-end work just described must also be done. This part of the chapter covers bottom-end services, which include servicing connecting-rod big-end bearings, crankshaft main bearings, crankshaft reed valves, and oil seals and gaskets.

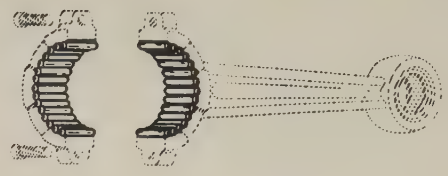
○ 31-14 CONNECTING-ROD SERVICE The rod big end can be checked for looseness while it is still attached to the crankshaft, as explained in ○ 31-11. The rod small end may have a needle bearing or a bushing. As explained in ○ 31-11, if it is a bushing (or sleeve bearing) and if it is worn, it can be replaced in many rods. In other rods, the bushing can be reamed to a larger size and an oversize pin fitted. In some engines, the bushing is not serviceable and, if worn, the rod is replaced.

In many small engines, particularly those used in motorcycles, a built-up crankshaft is used (see Fig. 10-9). In these, the crankshaft, connecting rod, and rod big-end bearing are replaced as an assembly. The big-end bearing usually is the needle type. Other small engines using needle bearings in the rod big end have a rod cap which can be removed so the rod can be taken off the crankshaft. Figure 31-29 shows this type.

○ 31-15 CONNECTING-ROD-NEEDLE-BEARING SERVICE If the connecting-rod big end uses needle bearings and they require replacement, proceed as follows: Figure 31-29 shows two styles of needle bearings: single-row and split-row. To install a new set of needles, lay the strip on your finger as shown in Fig. 31-30. Then carefully strip off the backing. Curl your finger with the needles around the crankpin. The grease on the needles will hold them in place, as shown in Fig. 31-30. The crankshaft and crankpin must be clean and the crankpin must be in good condition. See ○ 31-24 regarding crankshaft service.



(*a*) SPLIT ROWS OF NEEDLE BEARINGS



(*b*) SINGLE ROW OF NEEDLE BEARINGS

FIG. 31-29 Single-row and split-row needle bearings for connecting rods. (*Tecumseh Products Company*)

○ 31-16 CONNECTING-ROD-SLEEVE-BEARING SERVICE This type of bearing (Fig. 31-31) is used with a split-rod big end. The rod has a bearing cap so the two halves of the sleeve bearing can be installed (Fig. 10-8). There are three ways of checking the clearance between sleeve bearings and the crankshaft. These are with shim stock, with Plastigage, and with a micrometer and telescope gauge.

Before you check the clearance between the connecting-rod big-end bearing and the crankpin or the crankshaft, inspect the crankpin for wear and roughness. If the crankpin is worn, it will require service or the crankshaft will require replacement (see ○ 31-24).

To check the clearance with shim stock, lubricate a strip of 0.001-inch [0.025-mm] shim stock about 1/4 inch [6 mm] wide. Lay it lengthwise in the center of the bearing cap. Install the cap, and tighten the rod nuts to the specified torque. Try to move the rod endwise on the crankpin. If the rod has tightened up on the

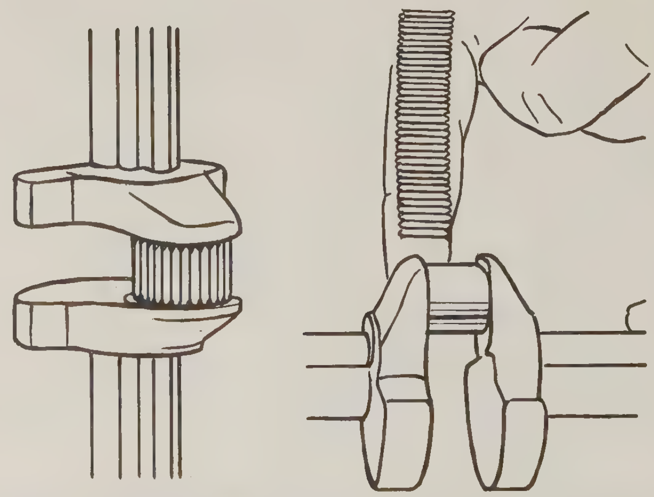
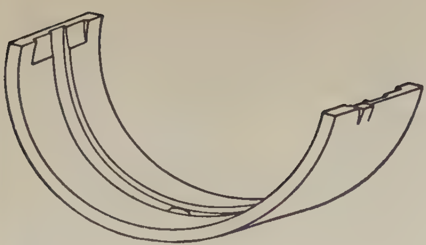


FIG. 31-30 (Left) Needles in place around the crankpin. (Right) Hold needles on finger to apply them to the crankpin. (*Lawn Boy Division of Outboard Marine Corporation*)



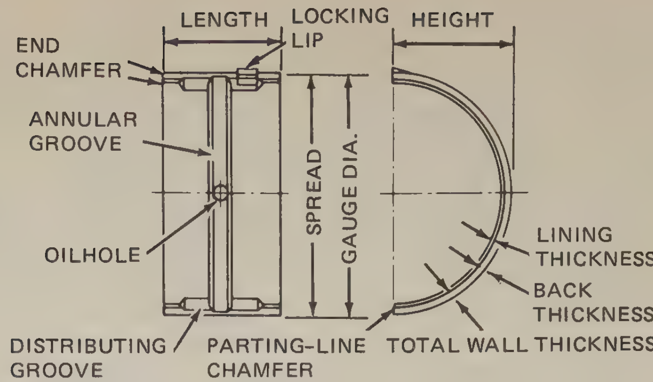


FIG. 31-31 (*left*) A typical sleeve-type bearing half. (*right*) A sleeve-type bearing half with the parts named. (*Federal Mogul Corporation*)

crankpin, the clearance between the bearing and the crankpin is less than the thickness of the shim stock. If the rod is still loose, the clearance is greater than the thickness of the shim stock. Lay another shim on top of the first, and tighten the rod nuts again. Repeat the checking procedure. If the rod is still loose, add another piece of shim stock. Repeat the procedure until the rod locks up. The bearing clearance is the thickness of the shims required to lock up the rod. Compare this thickness with the manufacturer's specifications. Excessive clearance means a new bearing is required.

Plastigage is a plastic wire that comes in strips. It flattens when pressure is applied to it. To use Plastigage, first make sure the bearing and crankpin are wiped clean of dirt and oil. Lay a strip of the Plastigage on the bearing in the rod cap as shown in Fig. 31-32. Then install the cap and rod on the crankpin, and tighten the nuts to the specified torque. Do not move the crankshaft while the Plastigage is in place. Remove the cap and measure the amount that the Plastigage has flattened, as shown in Fig. 31-32, using the scale that is printed on the Plastigage package. If the clearance is small, the Plastigage will have flattened considerably. If the clearance is relatively large, the Plastigage will not have flattened as much.

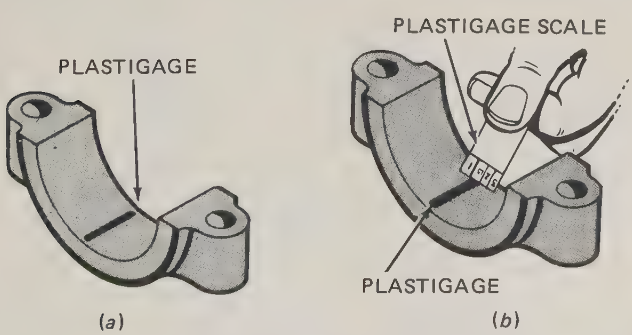


FIG. 31-32 Using Plastigage to check bearing clearance. (*a*) Lay a strip of Plastigage on the bearing in the rod cap. (*b*) After installing the cap and then removing it, measure the amount that the Plastigage has flattened to determine clearance.

When a micrometer and telescope gauge are used, the diameter of the bearing is measured with the telescope gauge. Then the crankshaft is measured with a micrometer. The clearance is found by subtracting the crankshaft diameter from the bearing diameter.

○ 31-17 INSTALLING NEW SLEEVE BEARINGS New connecting-rod bearings are required if the old ones are defective or have worn so much that the clearances are excessive. They also are required if the crankpins have become out-of-round or tapered. In such cases, a new or reground crankshaft with new bearings must be installed. See ○ 31-24 regarding crankshaft service.

Always check the crankpin as explained in ○ 31-24 to make sure it is not out-of-round or tapered. With either of these conditions, new bearings would soon fail.

When installing new bearings, make sure your hands, the workbench, your tools, and all engine parts are clean. Keep the new bearings wrapped until you are ready to install them. Handle them carefully. Wipe each bearing with a clean cloth just before installing it. Be sure that the bore in the cap and rod

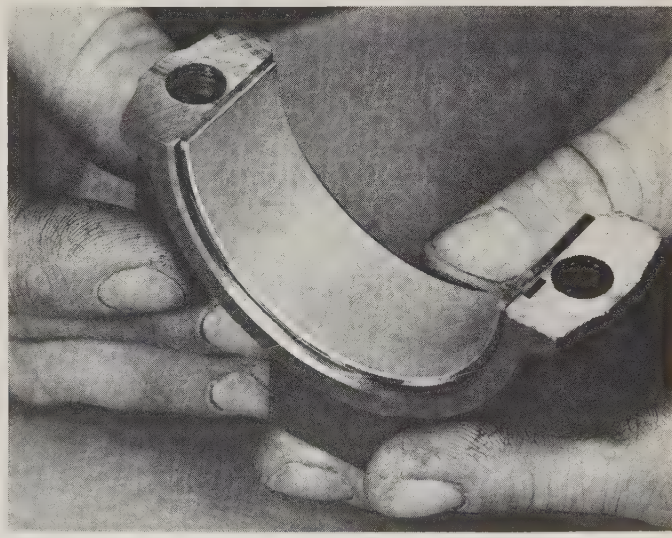


FIG. 31-33 Inserting a new bearing in the connecting-rod cap. (*Service Parts Division of Dana Corporation*)

are clean and not out-of-round. Some manufacturers recommend a check of bore roundness with the bearing shells removed. The cap is attached and the nuts drawn up to specifications. Then a telescope gauge and micrometer are used to check the bore. If it is excessively out-of-round, a new rod should be installed. If the bore is satisfactory, install the bearing (Fig. 31-33). If the bearing halves or shells have locking tangs, be sure they enter the notches provided in the rod and cap.

Bearing Spread Bearing shells are usually manufactured with "spread." The shell diameter is slightly greater than the diameter of the rod cap or rod bore into which the shell will fit. This is shown in Fig. 31-31. When the shell is installed in the cap or rod, it snaps into place and holds its seat during later assembling operations.

Bearing Crush To make sure that the bearing shell will "snug down" into its bore in the rod cap or rod when the cap is installed, the bearings have "crush." See Fig. 31-34. They are manufactured to have a slight additional height over a full half. This additional height must be crushed down when the cap is installed. Crushing down the additional height forces the shells into the bores in the cap and rod. It ensures firm seating and snug contact with the bores.

Never file off the edges of the bearing shells in an attempt to remove crush. When you select the bearings recommended by the engine manufacturer for an engine, they will have the correct crush. Precision-insert bearings must not be shimmed or filed to make them "fit better." This usually leads only to early bearing failure.

○31-18 BONDED ENGINE BEARING

On some connecting rods, the bearing is permanently bonded to the rod and cap. If this bearing is worn excessively, the complete rod must be replaced. However, some adjustment can be made to compensate for wear. This is done by removing shims from between the cap and rod. Clearance can be measured as for the replaceable sleeve bearings with shims, Plastigage, or telescope gauge and micrometer (○31-16). If clearance is excessive, shims can be removed from between the cap and rod to reduce it.

○31-19 CRANKSHAFT-BEARING SERVICE

The crankshaft of a single-cylinder engine is held at its ends by bearings. A variety of bearings have been used: needle, ball, tapered roller, and sleeve. Sleeve bearings may be of the split type, in which case they are checked and serviced as are connecting-rod split-sleeve bearings (○31-16 and ○31-17). Other crankshaft sleeve bearings are complete bushings pressed into the end plates of the crankcase. We discuss the servicing of the bushing type of sleeve bearing and needle, ball, and tapered roller bearings in following sections.

To gain access to the bearings, the crankshaft must be removed, and this requires removal of the flywheel. There are several methods of doing this, as explained in Chap. 26. Sometimes the flywheel must be removed to service the magneto. This procedure is also covered in Chap. 26.

○31-20 CRANKSHAFT SLEEVE-BEARING SERVICE

Several different sleeve-bearing-and-crankcase combinations have been used on small engines. This is because of the various crankcase materials and designs. In some engines with aluminum crankcases, no separate bearing is used. Instead, the crankshaft is supported by, and turns in holes bored in, the aluminum itself. If these holes wear, bearings can be installed as explained later, or a new crankcase or end plates are required.

Here is the procedure for checking and replacing sleeve bearings of the bushing type: First, wipe the bearing clean and inspect it for wear, scoring, or other damage. One manufacturer supplies "reject" gauges for checking the bearings in their engine. If the gauge can enter the bearing (Fig. 31-35), the bearing is worn and should be replaced ("rejected"). If a reject gauge is not available, the bearing can be

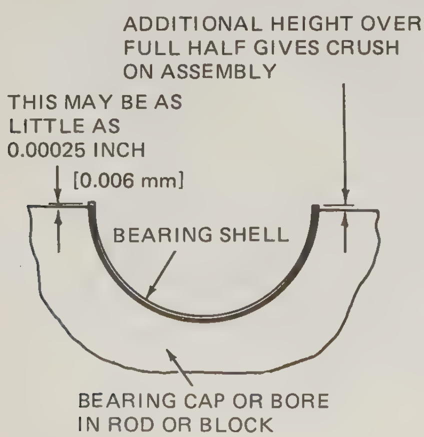


FIG. 31-34 Bearing crush.

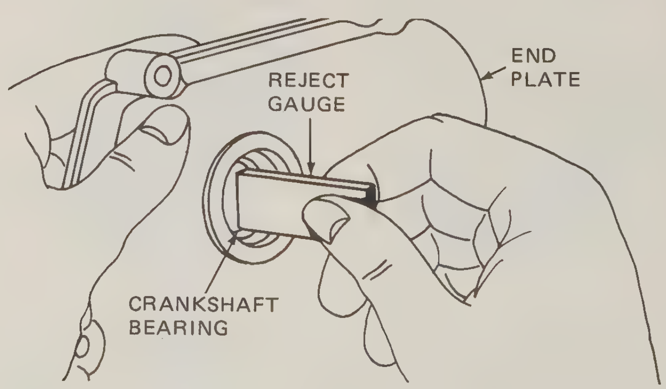


FIG. 31-35 Use a reject gauge to check the wear of a sleeve-type crankshaft bearing.

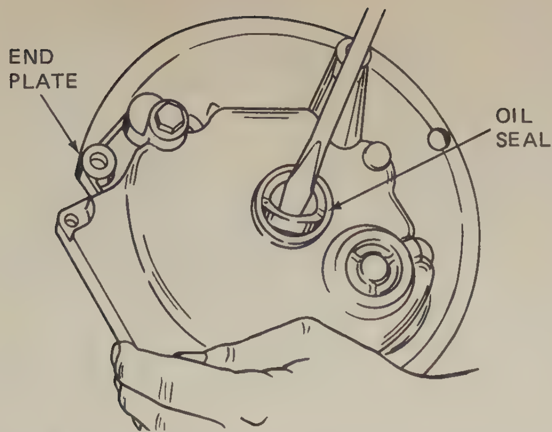


FIG. 31-36 Removing oil seal from the crankcase end plate. (*Tecumseh Products Company*)

checked with a small-hole gauge or a telescope gauge and micrometer.

In single-cylinder engines, the exposed end of the crankshaft is called the *power-takeoff* (PTO) end. For example, the end of the crankshaft of a power mower on which the cutting blade mounts is the PTO end. The other end of the crankshaft is the magneto end. The two bearings that support the crankshaft often are identified as the PTO bearing and the magneto bearing.

If new sleeve bearings are required, proceed as follows: After the crankshaft has been removed, reinstall the end plate. Remove the oil seal (Fig. 31-36). Then remove, install, and ream one bearing before removing the other bearing. In this way, the original bearing in the opposite end of the crankcase serves as a guide for reaming the new bearing. Then the newly installed and reamed bearing is used as a pilot for reaming the second bearing after it is installed.

To replace a sleeve bearing in the crankcase, first remove the PTO-end bearing. Use an arbor press or a bearing driver, and drive the old bearing toward the inside of the crankcase, as shown in Fig. 31-37. Support the crankcase or end plate around the bearing area while the old bearing is being removed and the new bearing installed. You can make these supports from old pieces of pipe. The supports prevent the bearing mounting area from distorting and the casting from cracking or breaking.

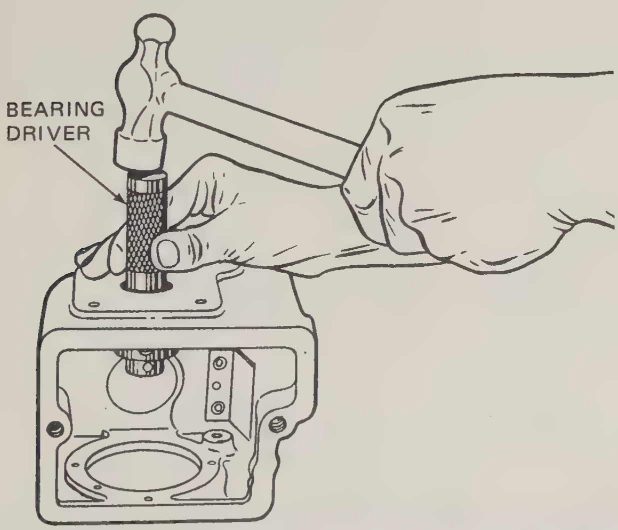


FIG. 31-37 Use of a bearing driver to remove or replace a sleeve bearing. (*Clinton Engines Corporation*)

Look for an oil hole in the crankcase and in the new bearing. If these are present, the new bearing must be installed so that the oil hole in the bearing aligns with the oil hole in the crankcase. Then press or drive the new bearing into place from the outside of the crankcase toward the inside. Drive the bearing into the crankcase to the proper depth, which is usually about $^{1}/_{16}$ inch [1.6 mm]. This allows room for installation of the oil seal later.

When the sleeve bearing is in position, ream it to the correct size. Each engine manufacturer makes available the proper size of reamers.

Two different types of reamers are used. The difference is in the pilot used for the reamer. One type of reamer uses a guide bushing placed in the opposite bearing as the pilot, as shown in Fig. 31-38. With the guide bushing in place, reassemble the crankcase and perform the reaming operation. Turn the reamer clockwise, slowly and steadily, until it is completely through the bearing. One manufacturer recommends that the bearing be reamed dry, without oil. However, if the reamer cuts slightly large, then use oil. The oil causes the reamer to cut slightly smaller. When the reamer is completely through the bearing, remove the end plate and take out the reamer. *Do not back the reamer out of the bearing*. This will gouge the bearing surface and damage the reamer. Check the bearing diameter for correct size. Then carefully clean out all chips and metal particles.

Aluminum engines without removable bearings are reamed as outlined above to take a new replaceable bearing. However, a different size reamer is used. After the new bearing bore is reamed, *the bearing*

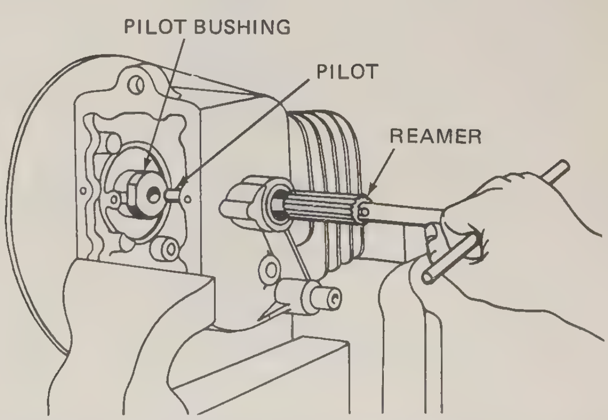


FIG. 31-38 Using a pilot and guide bushing in the original bearing to ream a newly installed sleeve bearing. (*Briggs & Stratton Corporation*)

must be staked in place. Make a notch in the bore with a chisel. The notch should be in the outer edge, opposite to where the split in the bearing will be after installation. Then install the bearing. With the chisel, notch the bearing above the notch in the bore. This will drive part of the bearing material into the outer notch and help prevent the bearing from turning. With the bearing staked in place, finish reaming it as outlined above.

○ 31-21 CRANKSHAFT NEEDLE-, ROLLER-, AND BALL-BEARING SERVICE To service ball, needle, or tapered roller bearings, first determine if the bearings are damaged or worn. After the crankshaft is removed from the engine, wash the bearing and then dry it. Do not spin-dry the bearing with compressed air. Depending on the engine, the bearing will remain in the crankcase or on the crankshaft. *Do not remove the bearing until you have decided that it must be replaced.* After the bearing is clean and dry, make a thorough visual inspection of it for pits and discoloration. If the bearing appears to be in good condition, coat it with oil. Then rotate the inner race of the bearing so you can determine by *feel* whether the bearing is tight or has rough spots.

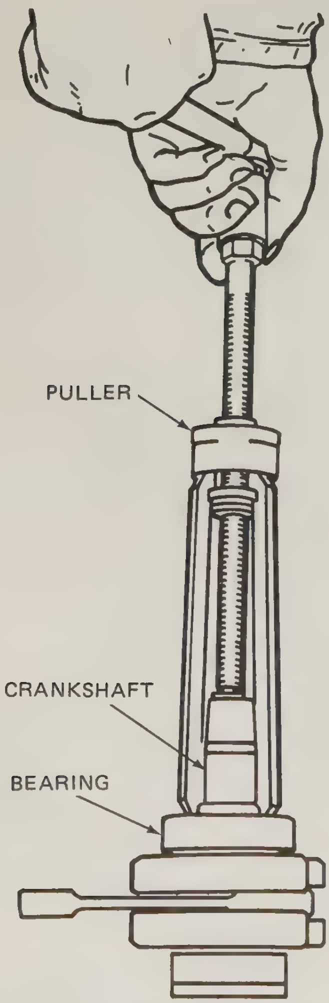


FIG. 31-39 Removing ball bearing from crankshaft with a puller. (*Kohler Company*)

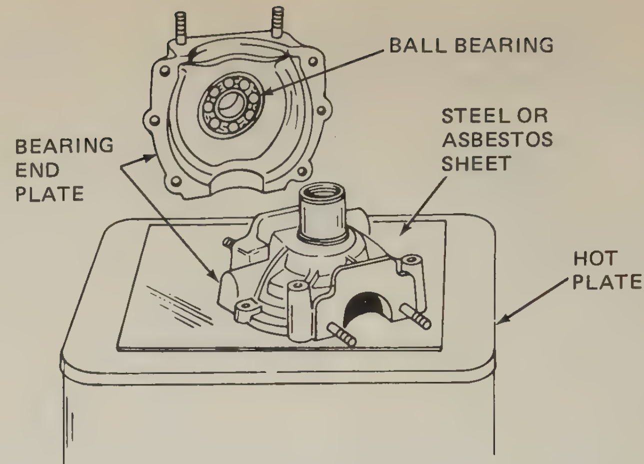


FIG. 31-40 Using a hot plate to heat the crankcase half and make it easy to remove ball bearing. (*Tecumseh Products Company*)

If the bearings are worn or damaged, they must be replaced. If the bearings are on the crankshaft, they should be pulled with a puller, as shown in Fig. 31-39, or pressed off with an arbor press. Then a new bearing can be pressed on.

If the bearings are in the crankcase, they may be pressed out or knocked out with a bearing driver. Another removal method, recommended by some engine manufacturers, is to put the crankcase half on a hot plate, as shown in Fig. 31-40. As the crankcase half reaches a temperature of about 400°F [204°C], the ball bearing should drop out. Tap the case lightly with a soft hammer to help loosen the bearing. The new bearing can be dropped into the case. Make sure it seats all the way into the recess for it. Wear heavy gloves when you must handle the hot case.

When the crankshaft is mounted on roller bearings, as shown in Fig. 31-41, you can replace the outer race in the housing by pulling the race. Another way is to heat the housing until the race drops out. Then install a new race. The inner race on the crankshaft must be pulled out with a puller and a new race pressed on.

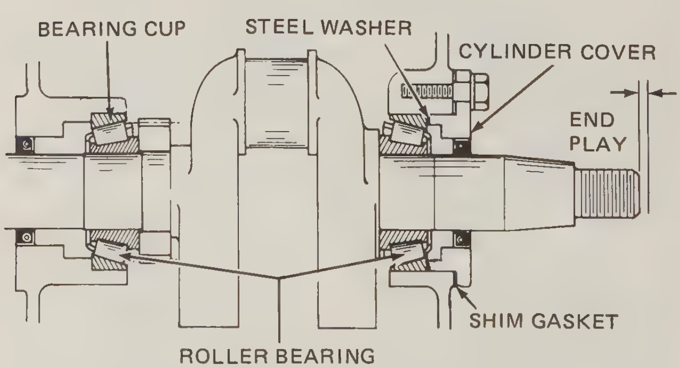


FIG. 31-41 Crankshaft mounted on tapered roller bearings. (*Tecumseh Products Company*)

Crankshaft needle bearings should be cleaned, dried, and coated with oil. Then check the needle bearings and their cage for wear. Replace the needle bearing when the needles are very loose or fall out of their cage. To install a new needle bearing, always drive the bearing on the end with the identification marks. But be very careful! If the new needle bearing assembly is damaged during installation, it will quickly damage the crankshaft.

○ 31-22 OIL SEALS On a two-cycle engine, the crankcase must be sealed. Although no oil is carried in the crankcase, air leaks must be prevented. Otherwise, the air-fuel mixture ratio will be changed and the engine may not run right. Oil seals on each end of the crankshaft prevent these leaks.

Oil seals should be discarded and new seals installed every time the engine is given a complete overhaul. Usually, oil seals are damaged during removal. One oil-seal arrangement is shown in Fig. 31-42. The seal is held in place by a retainer and snap ring. To remove the snap ring and seal, use a pointed tool to pry the snap ring out of the spiral groove. This permits removal of the spring, retainer, and seal. Figure 31-43 shows where the tool must be inserted to remove the snap ring.

Be careful not to use too much pressure while removing the spring. Excessive pressure on the pointed tool may damage the thin crankcase or scratch the seal surface on the crankshaft.

When installing new seals, many technicians coat the outside of the seal case with Permatex No. 3 or other liquid gasket sealer. Then, while the seal is being driven into place, the liquid sealer will fill in

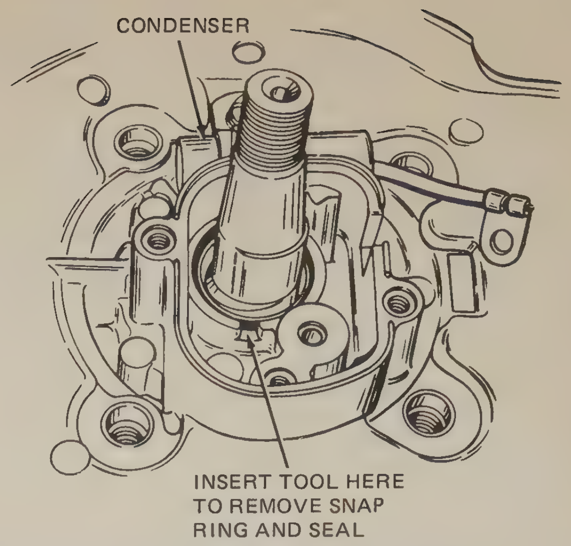


FIG. 31-43 Point at which tool must be inserted to remove snap ring. (*Tecumseh Products Company*)

any slight out-of-round condition of the seal or the seal bore. Some seals are made with a neoprene (plastic) coating for the same purpose. These can be installed without the use of liquid gasket sealer.

If you use a liquid sealer, be sure that it is applied to the seal and not to the bore in the block. Do not coat the bore in the block and then drive the seal in. Doing so allows the gasket sealer to get into the lip and may cause it to leak. Also, the sealer could possibly cause a leak by running into and blocking off the oil drain hole.

○ 31-23 GASKETS Always use new gaskets on engine reassembly. Old gaskets are probably hard and will not provide a good seal. In addition, they

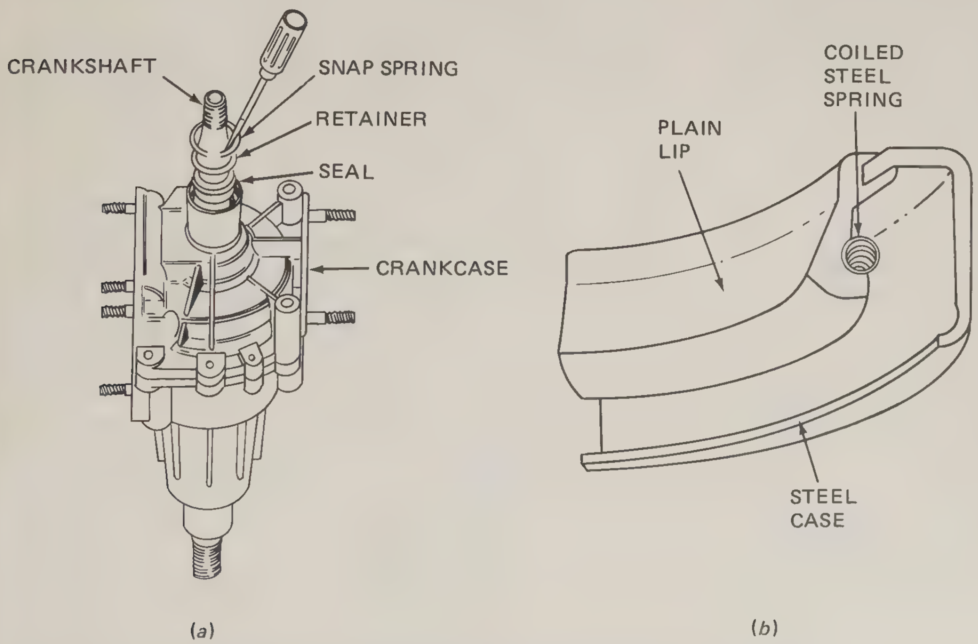


FIG. 31-42 (*a*) Removing snap ring to permit removal of oil seal. (*b*) Sectional view of a typical oil seal. (*Selastomer Division of Microdot, Inc.*)

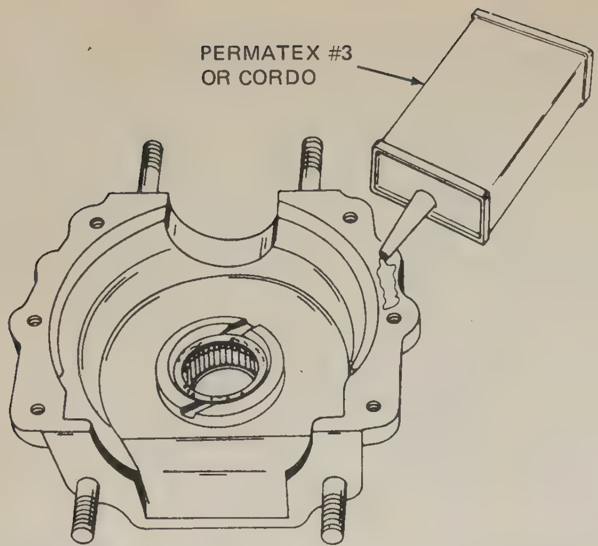


FIG. 31-44 Applying sealant to the contact face of one half of the split crankcase. (*Tecumseh Products Company*)

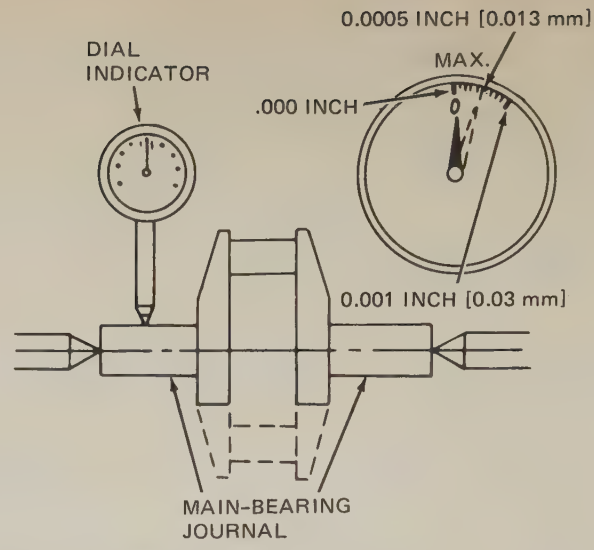


FIG. 31-45 Using a dial indicator to check main-bearing journals. (*Tecumseh Products Company*)

may have been damaged or destroyed during engine disassembly. Make sure that the sealing surfaces on the engine are clean, but do not scrape them. Instead, use lacquer thinner on a clean cloth to wipe traces of sealer or gasket material from the surfaces.

On the split-crankcase engine, the two halves of the crankcase are sealed by a bead of liquid gasket sealer. Apply the sealer to the contact face of one of the halves, as shown in Fig. 31-44.

○ 31-24 CRANKSHAFT SERVICE The crankshaft should be inspected for wear of the journals and for distortion. The crankshafts of power mowers, for example, can be bent if the cutting blade should strike a solid object a glancing blow. This could put a stress on the crankshaft that would bend it. A quick check for a bent crankshaft can be made with the crankshaft still in the engine. Remove the spark plug and crank the engine. Watch the end of the crankshaft for wobble. If there is wobble, the crankshaft is bent and it should be replaced.

With the crankshaft out of the engine, it can be inspected for roughness, discoloration, cracks and breaks, and stripped threads on the ends. Check the keyway for any enlarging or other damage that might have resulted from a loose flywheel, adapter, or pulley. Check the taper on the crankshaft where the flywheel mounts for wear or damage. Any damage, except for battered threads, means the crankshaft must be discarded. Battered threads can often be cleaned with a thread chaser.

Figure 31-45 shows various checks to be made on a crankshaft. After a thorough visual inspection, use a micrometer or dial indicator to check the crankpin and main journals. Mount the crankshaft on centers so it can be rotated. As the crankshaft rotates, any irregularity will cause the dial indicator needle to move. If journals are rough, out-of-round, or tapered, the crankshaft should be discarded.

○ 31-25 REED VALVES Not all two-cycle engines use reed valves. Those that do will not run right with a defective reed valve. When overhauling an engine, always clean all dirt and oil from the reeds and the adapter or reed-valve plate. Do this carefully to avoid damaging reeds. If reeds are bent, damaged, or broken, replace the reed-valve assembly. Check also, on engines using a reed-valve stop, to make sure the stop is not bent or broken. Use a feeler gauge as shown in Fig. 31-46 to check how much the reeds bend away from the base plate, or adapter. One manufacturer specifies a maximum of 0.010 inch [0.25 mm]. If the reeds bend more than this, or are otherwise damaged, replace them.

Do not attempt to check reed-valve action with compressed air. This can damage the reeds. Reed valves are checked by visual inspection only.

○ 31-26 BREAKING IN AN OVERHAULED ENGINE Allow a new or overhauled engine to work up to full power gradually. On two-cycle engines, adjust the carburetor for a fairly rich mixture for the first 10 hours. Follow the instructions on the nameplate at-

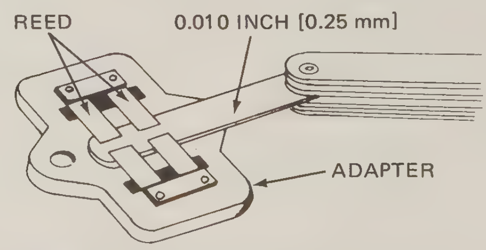


FIG. 31-46 Measure how far the reeds bend away from the adapter. (*Tecumseh Products Company*)

tached to the engine or equipment. See also ○ 30-2 for further information on operating a new or rebuilt engine.

REVIEW QUESTIONS

1. What is a top-end overhaul?
2. When is it necessary to remove the engine from a machine in order to do a top-end overhaul?
3. While the cylinder is off of the crankcase, why should the crankcase opening be covered with a shop towel?
4. List the different ways that the piston can be removed from the connecting rod.
5. What causes the exhaust ports to clog in a two-cycle engine?
6. What three conditions of a cylinder can be checked with an inside micrometer?
7. How can you tell if a cylinder has a cast-iron liner?
8. What is the difference between a chrome-plated cylinder bore and a cast-iron liner?
9. Explain how to hone a cylinder.
10. After honing, how is the cylinder cleaned?
11. What do you do about a piston that has a broken ring land?
12. Explain how to check piston clearance.
13. Why should a wire brush never be used to clean a piston?
14. How do you check for ring-groove wear?
15. When can piston rings be reused?
16. List the types of piston rings used in two-cycle engines.
17. Describe how to check the piston-pin bearing.
18. How do you check for connecting-rod bearing wear without disassembling the engine?
19. Explain how to use Plastigage to check bearing clearance.
20. Why are bearing spread and bearing crush important?
21. What type of crankcase metal can be used by itself as the bearing surface?
22. What names are used to identify the two ends of a crankshaft?
23. What is a sleeve bearing?
24. Explain how to ream new sleeve bearings after installation in the crankcase.
25. Why must the crankcase of a two-cycle engine have seals although no oil is carried in the crankcase?

SELF PROJECT

Locate a shop engine or an old engine that you can disassemble. Clean the outside of the engine and prepare it for disassembly. Next, disassemble the engine and perform each of the inspections and checks covered in this chapter. When you are finished with each step, have your instructor inspect your work. In this way, you will learn how to use the tools and shop equipment that are needed by the small-engine technician in performing a small-engine overhaul.

32
Chapter

Servicing Four-Cycle Engines

After studying this chapter, you should be able to:

1. Explain the difference in service procedures required for four-cycle engines
2. Discuss the use of short blocks
3. Demonstrate how to adjust the valves on various types of small engines
4. Demonstrate how to perform a complete valve-service job
5. Demonstrate how to check the valve springs and tappets
6. Demonstrate how to service valve guides
7. Demonstrate how to grind valve seats
8. Explain how to install a valve-seat insert
9. Demonstrate how to inspect and check a camshaft

○ 32-1 SPECIAL SERVICING PROCEDURES FOR FOUR-CYCLE ENGINES There are many servicing procedures that are the same for two-cycle and four-cycle engines. For example, the servicing procedures for both are the same for the cylinder, pistons, piston rings, connecting rod, crankshaft, and the rod and crankshaft bearings. These service procedures are all covered in detail in Chap. 31.

However, there are several special procedures that the four-cycle engine requires. These include adjusting the valves, servicing valves and valve seats, and servicing the camshaft and camshaft bearings. We cover these special services in this chapter.

○ 32-2 SHORT BLOCKS Small engines are relatively inexpensive. Repair time and parts are relatively costly. If an engine is worn so badly that a new piston, rings, connecting rod, and bearings are required, it may cost more to overhaul the engine than to buy a new one. However, it may not be necessary to buy a complete engine. Some engine manufacturers supply "short-block" engine assemblies (Fig. 32-1). These are assembled engines minus magneto, cylinder head, carburetor, and starter. When these parts are still good, the short block may be the answer to a service problem. The short block includes the cylinder block, piston rings, connecting rod, crankshaft, and, on four-cycle engines, the valves and camshaft.

For engines that can be repaired with still fewer parts, a "miniblock" is available from some manufacturers (Fig. 32-2).

○ 32-3 VALVE ADJUSTMENTS Before we examine the grinding of valves and valve seats, servicing of camshafts, and other valve-related services, let us look at valve adjustments.

On most four-cycle small engines, periodic adjustment of the valves is required. Actually, this adjustment sets the proper amount of clearance in the valve

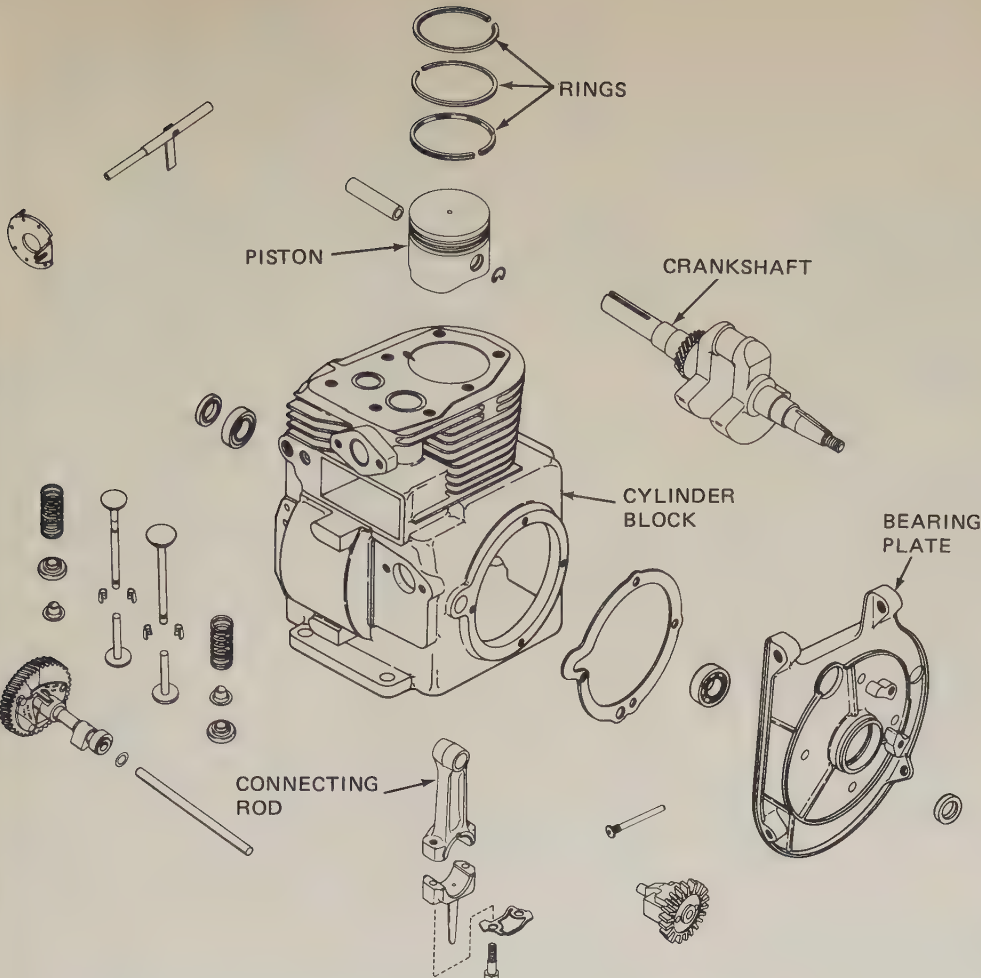


FIG. 32-1 Short block for a small engine. (*Kohler Company*)

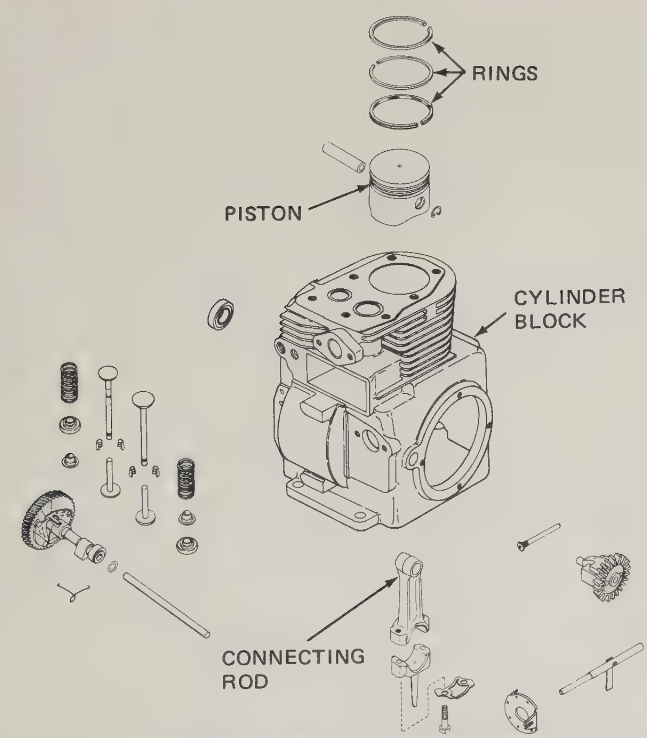


FIG. 32-2 Miniblock assembly for a small engine. (*Kohler Company*)

train. There must be some clearance to assure complete closing of the valves. The adjustment procedure varies with the type and design of engine. The procedure has several names—adjusting valve-lifter clearance, adjusting valve-tappet clearance, adjusting valve lash—but all refer to the same basic adjustment. Some engines using hydraulic valve lifters normally require no clearance adjustment. Others require checking and adjustment whenever valve-service work is performed. The procedures that follow are typical.

○ 32-4 L-HEAD ENGINE WITH MECHANICAL VALVE LIFTERS Some specifications call for checking the clearance with the engine cold. According to other specifications, the engine should be warmed up and idling. Remove the valve-cover plates. Figure 11-2 shows the valve mechanism on an L-head engine. Use a feeler gauge to check the clearance between the valve stem and the adjusting screw in the valve lifter as shown in Fig. 32-3. A two-step "go, no-go" feeler gauge of the specified thicknesses can be used. Adjustment is correct when the "go" step fits the clearance but the "no-go" step does not.

If the clearance is not correct, the adjusting screw must be turned in or out as necessary to correct it. Some tappet-adjusting screws are self-locking. Oth-

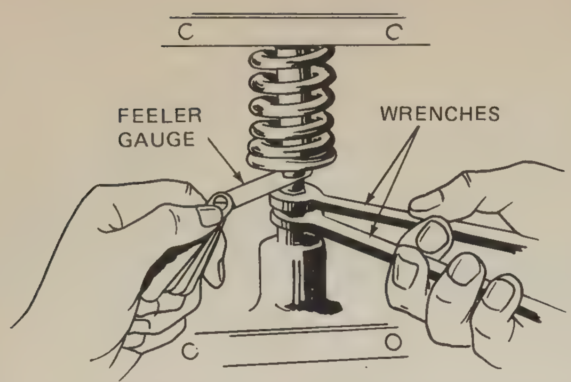


FIG. 32-3 Adjusting valve-tappet clearance on an L-head engine.

ers have a locking nut. On the latter type, the locking nut must be loosened. This requires two wrenches: one to hold the screw, the other to turn the nut. On both types of tappet-adjusting screws, one wrench must be used to hold the valve lifter while a second wrench is used to turn the adjusting screw. Adjustment is correct when the feeler gauge can be moved between the screw and valve stem with some drag when the valve is closed. When a locking nut is used, it should be tightened after the adjustment is made and the clearance should be checked again. After the adjustment is completed, replace the cover plates, using new gaskets.

○ 32-5 OVERHEAD-VALVE ENGINE WITH MECHANICAL VALVE LIFTERS Most specifications call for making the check with the engine cold and not running. First, remove the valve cover. Measure the clearance between the valve stem and rocker arm, as shown in Fig. 32-4. The clearance is measured with the valve lifter on the base circle of the cam. Turn the crankshaft with the starter until the base circle of the cam is under the valve lifter.

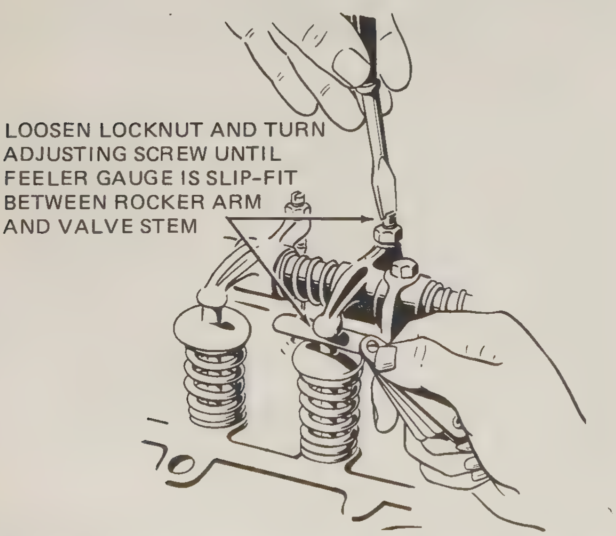


FIG. 32-4 Adjusting valve-tappet clearance on an overhead-valve engine.

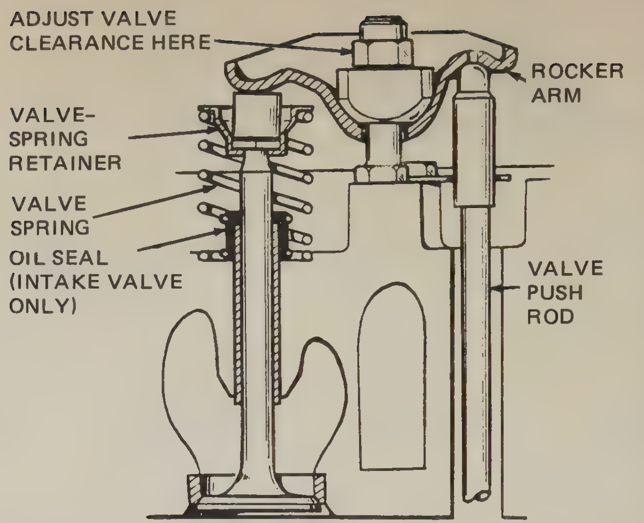


FIG. 32-5 Adjusting valve-tappet clearance on an engine with rocker arms independently mounted on ball studs. Backing the stud nut out increases clearance. (*Onan Corporation*)

There are two kinds of rocker arms. One is shaft-mounted, and the other is ball-stud-mounted. The shaft-mounted type usually has an adjustment screw. This screw is normally self-locking and does not require a locking nut. Use a box wrench to turn the adjustment screw and adjust the clearance to specifications. Do not use an open-end wrench. This could damage the screwhead.

On the ball-stud-mounted rocker arms (Fig. 32-5) turn the self-locking rocker-arm nut to make the adjustment. Turning the nut down reduces clearance.

○ 32-6 ENGINES WITH HYDRAULIC VALVE LIFTERS On some engines with hydraulic valve lifters, no adjustment is provided in the valve train. In normal service, no adjustment is necessary. The hydraulic valve lifter takes care of any small changes in the valve-train length. However, adjustment may be needed if valves and valve seats are ground. Unusual and severe wear of the push-rod ends, rocker arm, or valve stem may also require adjustment. Then some correction may be required to re-establish the correct valve-train length. The procedures vary, so follow the steps in the manufacturer's service manual.

○ 32-7 OVERHEAD-CAMSHAFT ENGINES Overhead-camshaft (OHC) engines have several arrangements for carrying the cam action to the valve stems. In some engines, cam action is carried directly to the valve stem through a cap, called the valve tappet. This cap fits over the valve stem and spring. In other engines, the cam action is carried through a rocker arm. We shall look at both arrangements. Checks and adjustments are made with the engine cold, after the engine has cooled overnight or has not been operated for at least four hours.

Figure 32-6 shows two arrangements that are used

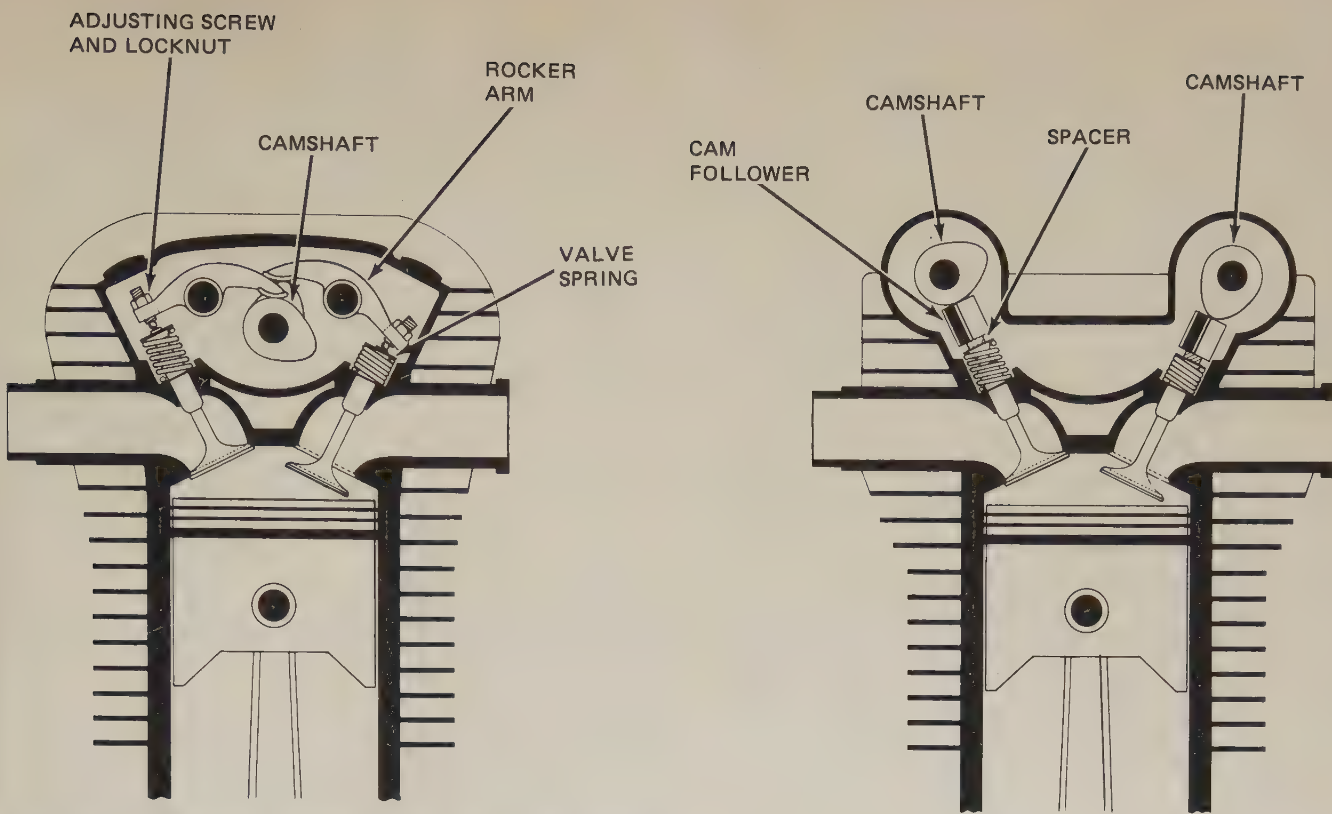


FIG. 32-6 Valve and camshaft arrangement for a single-overhead-camshaft engine and for a double-overhead-camshaft engine. (*Honda Motor Company, Ltd.*)

to actuate the valves by means of an overhead camshaft. In some engines the cam operates the valve directly. Other engines use rocker arms to transfer cam motion to the valve. When only one camshaft is used, as shown in the left illustration of Fig. 32-6, the engine is identified as having a single overhead camshaft. This is often abbreviated *SOHC*. When an engine has two camshafts—one camshaft to operate the intake valves and a second camshaft to operate the exhaust valves—the engine is known as a double overhead camshaft (DOHC) engine.

A valve-clearance adjustment on an overhead-camshaft engine using rocker arms is made in the same manner as for the overhead-valve engine shown in Fig. 32-4. The adjustment is made with the piston at TDC on the compression stroke, when both valves are closed. Most engines have timing marks indicating this position. However, in a four-cycle engine, when the timing marks line up, the engine could be at TDC ending the compression stroke or at TDC ending the exhaust stroke. A quick way to tell if the valves are in position to adjust, or if the engine should be cranked one complete revolution, is to wiggle the rocker arms up and down. Both should have a slight amount of free movement up and down. If either rocker arm is tight, then turn the engine one full revolution. On multicylinder engines, crank the engine until the piston in each cylinder is in proper position for valve adjustment.

Insert a feeler gauge of the specified thickness in the space between the rocker arm and the valve stem, as shown in Fig. 32-7. If the gauge goes in with a slight drag, the valve has the proper clearance. However, if the gauge will not go in, the valve does not have enough clearance. When the gauge slips through the space freely with no resistance, the clearance is excessive and must be reduced.

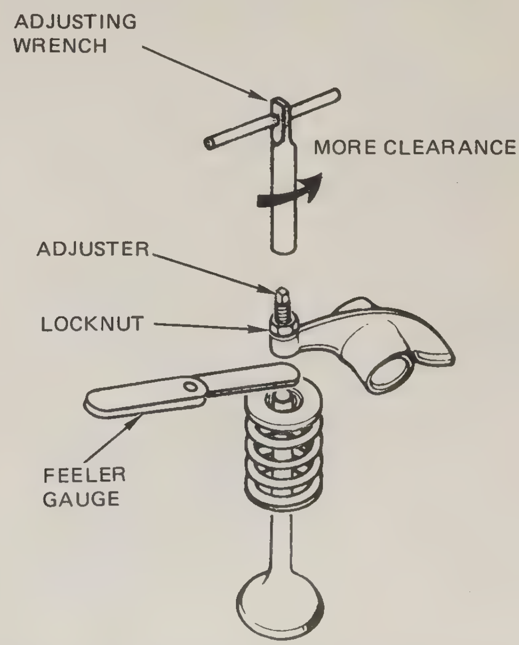


FIG. 32-7 Adjusting valve clearance on an overhead-camshaft engine that has rocker arms. (*Honda Motor Company, Ltd.*)

The adjuster and locknut on many rocker arms can be set using a wrench and a screwdriver. This is the method shown in Fig. 32-4. Some engines require a special adjusting wrench, as shown in Fig. 32-7, to fit the rocker-arm adjuster. To set the clearance, first use a wrench to loosen the locknut. Then use the adjusting wrench to make the clearance adjustment. Basically, the adjuster is a machine screw. Turning it clockwise lengthens the distance the screw sticks out below the rocker arm. This reduces the clearance. Turning the adjuster counterclockwise increases the clearance between the end of the screw and the valve stem.

When you feel a slight drag on the feeler gauge while turning the adjuster, the clearance is correct. Remove the feeler gauge, and tighten the locknut. Then recheck the clearance again. Sometimes tightening the locknut changes the clearance slightly.

Figure 32-8 shows an exploded view of the valve train in a single-overhead-camshaft marine engine. Notice that in this engine the cams are direct-acting. By "direct-acting," we mean that the cams work directly on the cam follower, or tappet. No rocker arm is used. To check the valve clearance, rotate the crankshaft until both valves close. Then insert the feeler gauge between the cam and the cam follower, as shown in Fig. 32-9. Record the clearance, then repeat the procedure for each valve.

When any valve has incorrect clearance and you decide to adjust it, you must prepare a chart similar to the one shown in Fig. 32-10 for each valve. In this type of valve train, valve clearance is adjusted by changing the cam-follower spacer, which is available in a variety of thicknesses. As you can see in Fig. 32-11, the spacer fits between the valve stem and the cam follower.

To adjust the clearance, remove the camshaft and camshaft bearings. On each valve that requires clearance adjustment, lift off the cam follower and remove the cam-follower spacer. Measure the thickness of each spacer, or shim, and enter the measurement in the chart. Then fill out the chart to determine how thick the new spacer must be. When you have the new spacer in place, make a quick check as shown in Fig. 32-11 to be sure that the spacer protrudes above the valve-spring retainer by at least 0.002 inch [0.05 mm]. If it does not, the valve must be replaced. After checking the spacer, install the cam follower on the same valve from which it was removed. Then reinstall the camshaft bearings and camshaft.

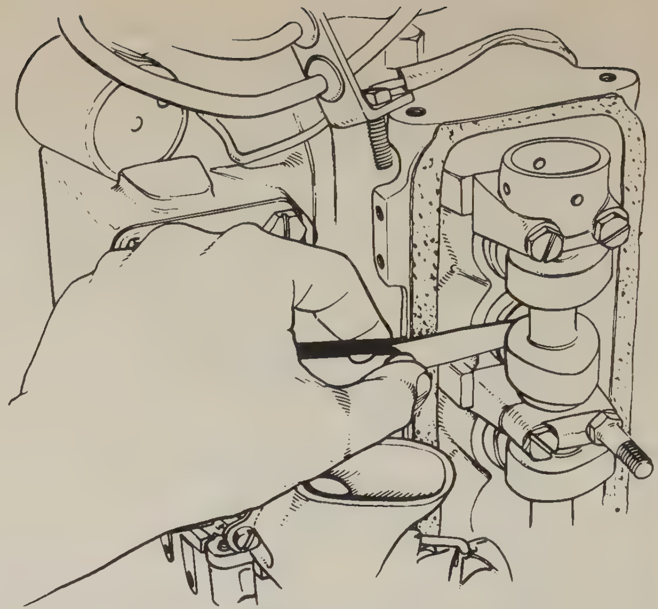


FIG. 32-9 Checking valve clearance on the overhead camshaft engine shown in Fig. 32-8.

○ 32-8 THE COMPLETE VALVE JOB In addition to adjusting valves, other jobs relating to the valves may be required on four-cycle engines. These include removing the cylinder head, removing and servicing the valves, servicing valve seats and valve guides, and installing new valve-seat inserts if required. We cover these procedures on following pages.

The procedures that follow apply generally to single-cylinder L-head air-cooled engines. They may also apply to other engines. However, if available, have the service manual in front of you whenever you start out to service an engine that is new to you.

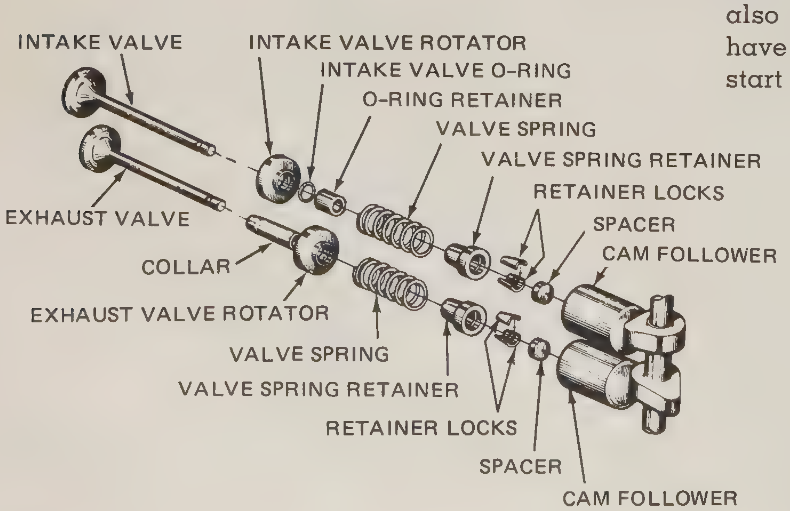


FIG. 32-8 Exploded view of the valve train of a direct-acting single-overhead-camshaft outboard engine. (*Homelite*)

VALVE NUMBER	SAMPLE	1	2	3	4	5	6	7	8
ORIGINAL VALVE CLEARANCE AS MEASURED	0.008 INCH [0.20 mm]								
ADD THICKNESS OF ORIGINAL SPACER AS MEASURED	0.106 INCH [2.69 mm]								
GIVES YOU	0.114 INCH [2.90 mm]								
SUBTRACT REQUIRED VALVE CLEARANCE. 0.012–.014 INCH [0.30–0.36 mm] INTAKE VALVES 0.015–.017 INCH [0.38–0.43 mm] EXHAUST VALVES									
TO GET THICKNESS OF REQUIRED SPACER	0.097 INCH [2.46 mm]								

FIG. 32-10 Chart for calculating the thickness of the shim or spacer needed to adjust valve clearance in the engine shown in Fig. 32-8.

A complete valve job requires the following steps. The details of valve and valve-seat service are described immediately afterwards. Listed below are the steps for doing a complete valve job. All steps may not apply to a specific engine that you are servicing.

1. Remove the air cleaner and disconnect the throttle linkage, fuel line, and any air and vacuum hoses from the carburetor.
2. Remove or set aside the necessary lines and hoses to get at the cylinder head.

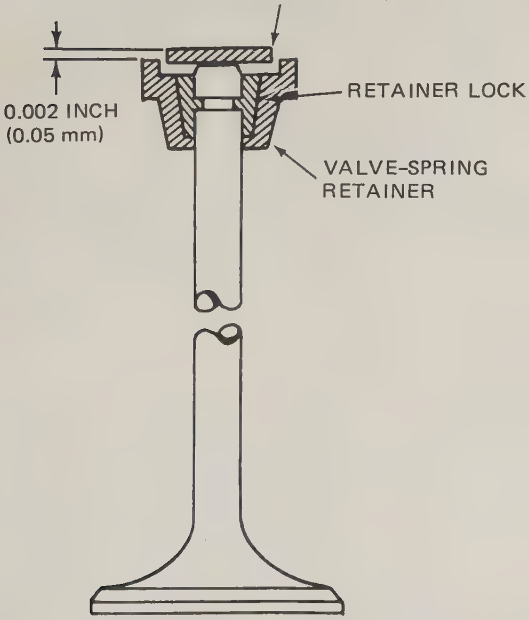


FIG. 32-11 Position of the cam-follower spacer in the valve train. (*Homelite*)

3. Disconnect the spark-plug wires and temperature-sending unit, if used.
4. Remove the crankcase ventilating system, if used.
5. On overhead-valve engines, remove the carburetor and intake manifold. On many L-head engines, it is not necessary to remove the carburetor.
6. Remove the rocker-arm cover or covers.
7. On engines with rocker arms supported on shafts, remove the shaft assembly or assemblies. Then remove the push rods in order.
8. Remove the head bolts. Take the head off the engine.
9. Remove the valves and springs from the head or block. To avoid damaging or breaking the valve guide, do not pull out by hand a valve with a mushroomed stem end. The mushroom must be removed by grinding it off with a grinding stone. Keep the removed valves and springs in proper order so that they can be put back into their proper positions.
10. Check valves and valve seats. Clean the valve heads and stems on a wire wheel. Grind the valve seats and reface valves as necessary. Check valve seating. Reface and chamfer valve-stem ends if necessary. If you are installing new valves of the coated type, do not reface them. Refacing or lapping coated valves removes the protective coating and greatly shortens valve and seat life.
11. Check rocker arms for wear. Service or replace them as necessary.

12. Check valve guides for wear. Clean, replace, or knurl and ream for same-size valve stem if necessary. Or ream for a larger-diameter valve stem.
13. Reinstall valves and springs.
14. Install head, push rods, rocker arms, rocker-arm cover, and other parts removed during head removal.
15. Check and adjust valve-stem clearance as necessary.

○ 32-9 REMOVING THE CYLINDER HEAD Follow the general instructions above for removing the cylinder head, remembering never to remove a cylinder head from a hot engine. Wait until the engine cools. If the head is removed hot, it can warp so that it cannot be used again. Slightly loosen all cylinder-head bolts first to ease the tension on the head. Then remove the bolts and take off the head as shown in Fig. 32-12. If the head sticks, carefully pry it loose. Do not pry hard. Do not insert the pry bar too far between the head and the cylinder. This could mar the mating surfaces and lead to leaks. Lift the head off, and place it on a piece of wood or heavy cardboard.

As you remove the cylinder-head screws, be sure to note where the long and short screws go. If you try to put a long screw in a short-screw hole during reassembly, it might bottom and break off a fin or leave the cylinder head loose. If you put a short screw in a long-screw hole, it may not engage enough threads to hold and may either strip the upper threads or else not retain its hold, leaving the cylinder head loose.

○ 32-10 VALVE REMOVAL For such services as valve or valve-seat grinding, valve-seat insert replacement, and valve-guide cleaning or replacement, the cylinder head and valves must be removed from the engine. Care must be used to avoid interchanging the valves while they are out of the engine. During assembly, each valve must be installed in the same valve port from which it was removed. A valve rack in which valves with their springs, retainers, and locks can be placed in proper order is recommended. If you do not have a valve rack, you can make one easily, like the one shown in Fig. 32-13. However, an old muffin pan from the kitchen will do. Keep the valve-train parts—valve, spring, retainer lock—together as a set.

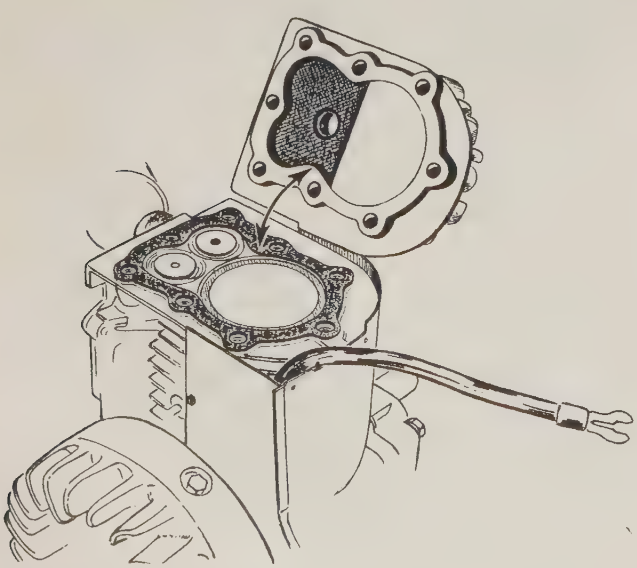


FIG. 32-12 Removing cylinder head from a small L-head engine. (*Clinton Engines Corporation*)

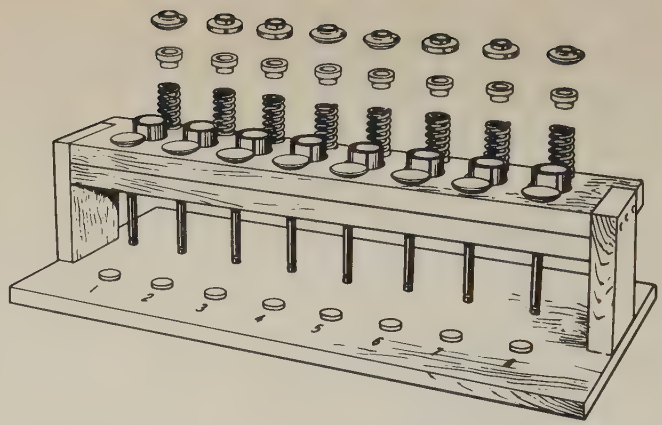


FIG. 32-13 Valve rack for holding valves and valve-train parts. (*Homelite*)

Different tools and valve-removal procedures must be used for different engines. Let us look at these various procedures.

Because of the interference of the manifolds, on some L-head engines you must remove the manifolds from the cylinder block before attempting to remove the valves. Next, you remove the cover plate from the tappet chamber. A valve-spring compressor then is used to compress the valve spring so that the valve-retainer lock or keeper can be removed from the valve stem. Various types of retainer locks are used. Care must be exercised to prevent the lock from falling down into the crankcase, where it might jam into moving parts and cause serious damage. Any openings through which the lock could fall into the crankcase should be temporarily closed with clean cloths.

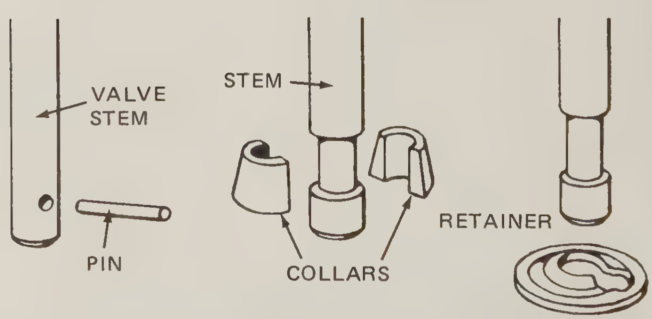


FIG. 32-14 Different types of valve-spring retainers and locks. (*Briggs & Stratton Corporation*)

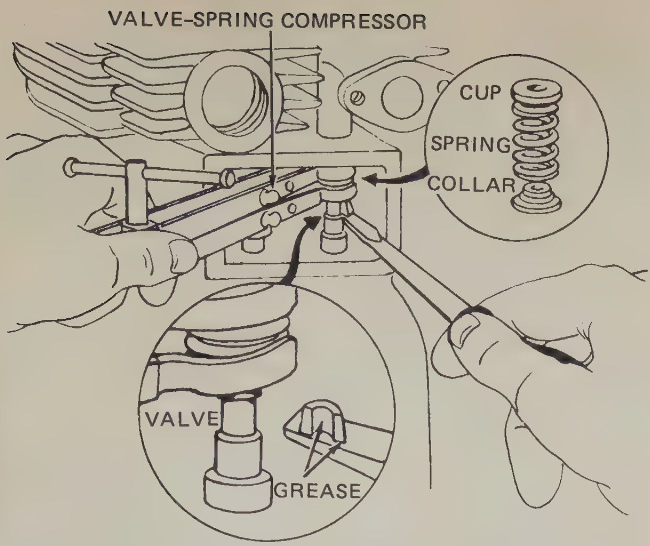


FIG. 32-15 Removing valve spring on engine using split-collar retainer. (*Briggs & Stratton Corporation*)

Special tools are available that will catch and hold the lock when it is released. Some manufacturers recommend the use of a magnet to hold the lock when it is released so that it will not fall into the crankcase.

There are three general types of valve-spring retainers, as shown in Fig. 32-14: pin, split-collar, and one-piece. To remove the pin or split type, use a spring compressor, as shown in Figs. 32-15 and 32-16. Adjust the jaws of the compressor until they just touch the top and bottom of the valve chamber. This will keep the upper jaw from slipping into the coil of the spring. Push the compressor in until the upper jaw slips over the upper end of the spring. Then compress the spring by tightening the jaws. On the split-collar type, put a little grease on a screwdriver, as shown in Fig. 32-15, to remove the retainer. On the pin-type use needle-nose pliers to pull out the pin, as shown in Fig. 32-16.

On the one-piece type, shown in Fig. 32-17, move the retainer around so the larger part of the opening clears the undercut in the valve. Then, on all types, lift the valve out and remove the compressor with the spring.

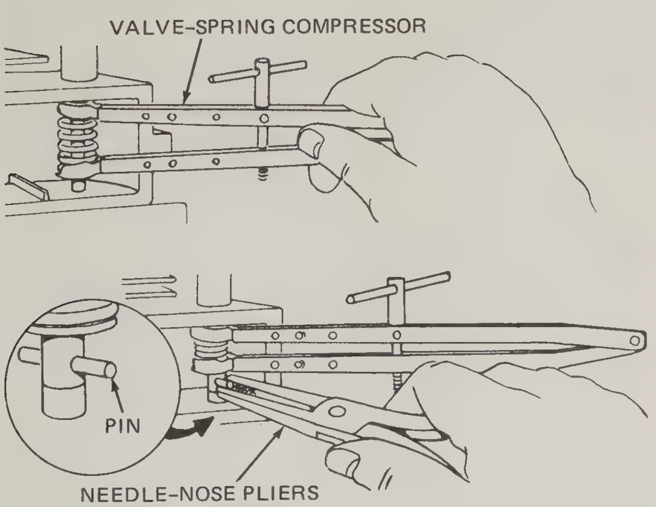


FIG. 32-16 Removing valve spring on engine using pin retainer. (*Briggs & Stratton Corporation*)

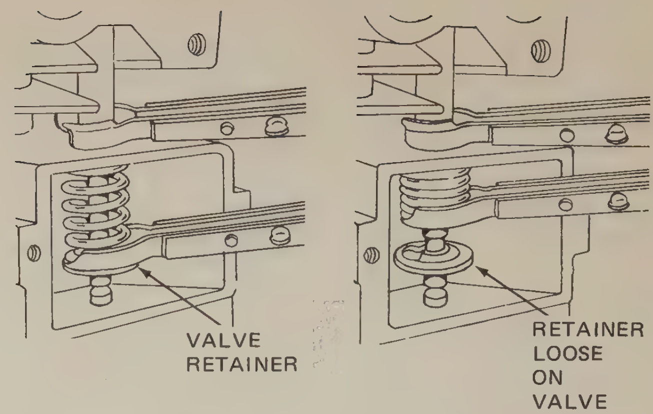


FIG. 32-17 Removing valve spring on engine using one-piece retainer. (*Briggs & Stratton Corporation*)

Other types of valve-spring compressors are widely used. Figure 32-18 shows the automotive C type being used to compress the valve spring. This type of valve-spring compressor is very versatile, and it is practically a must for use on overhead-valve engines.

○ 32-11 SERVICING VALVES Figure 32-19 shows the various parts of the valve to be inspected. Check the valve-seating faces for wear, burned spots, pits, cracks, and other signs of damage. If the face seems to be in good condition but is somewhat worn or

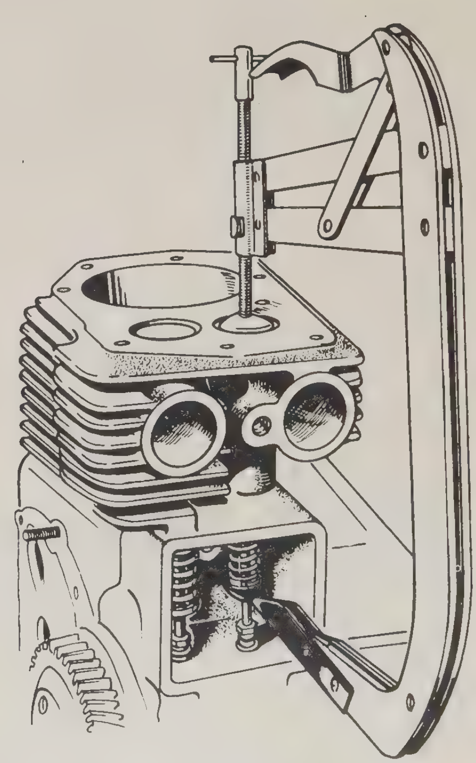


FIG. 32-18 Using the automotive type of valve-spring compressor. (*Onan Corporation*)

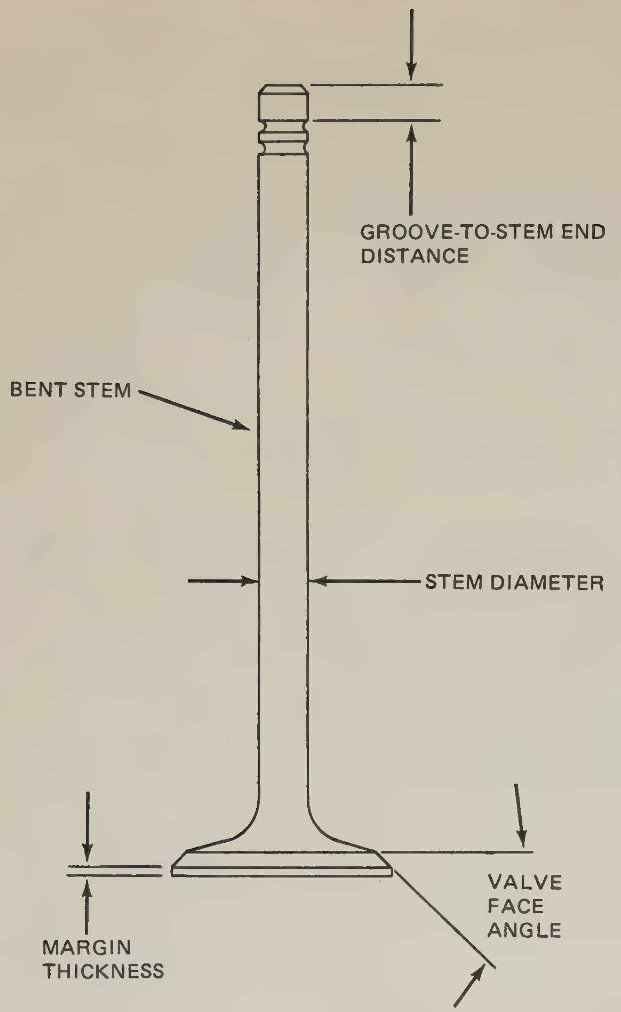


FIG. 32-19 Parts of the valve to be checked. For the dimensions, refer to the manufacturer's specifications.

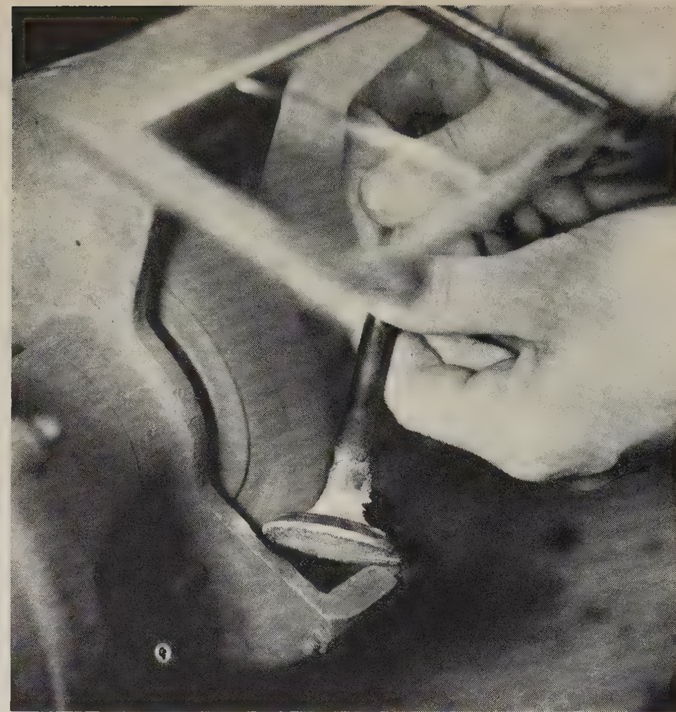


FIG. 32-21 Cleaning a valve on a wire wheel. (*TRW, Inc.*)

burned, it can be refaced on a valve-refacing machine. Also, check the valve-stem diameter with a micrometer. Figure 32-20 shows typical valve and seat dimensions as recommended by Briggs & Stratton. If the valve face looks to be too badly worn or otherwise damaged to clean up in the valve-refacing machine, or if the valve stem is worn or bent, discard the valve.

Clean the carbon off the valves with a wire wheel, as shown in Fig. 32-21. Always wear goggles to protect your eyes from flying particles of metal and dirt. Polish the stems, if necessary, with a fine grade of emery cloth. Do not take off more than the dirty coating on the surface. You must not remove any metal from the stem. Be careful also not to scratch the valve-seating surface or valve stem with the wire brush or emery cloth.

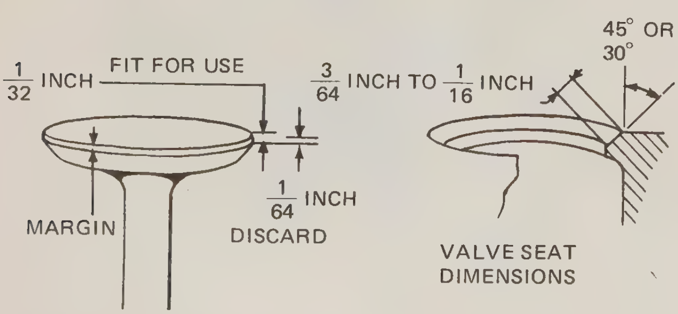


FIG. 32-20 Valve and valve-seat dimensions. (*Briggs & Stratton Corporation*)

As you clean the valves, re-examine them to make sure all are usable. Small pits or burns in the valve face can be removed by grinding the valve. Larger pits or grooves are hopeless. New valves will be required. Figure 32-19 shows specific parts of the valve to be examined. Eccentricity, otherwise known as a bent stem, can be checked in the valve grinder. If the runout, or eccentricity, is excessive, discard the valve.

○ 32-12 REFACING, OR GRINDING, VALVES If the valves are good enough to reuse, the next step is to reface, or grind, them. This process requires a valve-refacing machine like the one shown in Fig. 32-22. The machine has a grinding wheel, coolant delivery system, and chuck that holds the valve for grinding. Set the chuck to grind the valve face at the specified angle. This angle must just match the valve-seat angle or be the interference angle recommended by the engine manufacturer. Then put the valve into the chuck and tighten it. The valve should be deep in the chuck, so that not too much sticks out. Otherwise the valve can slip during grinding, and the result will be a poor grinding job.

To start the operation, align the coolant feed so that it feeds coolant on the grinding wheel. Then start the

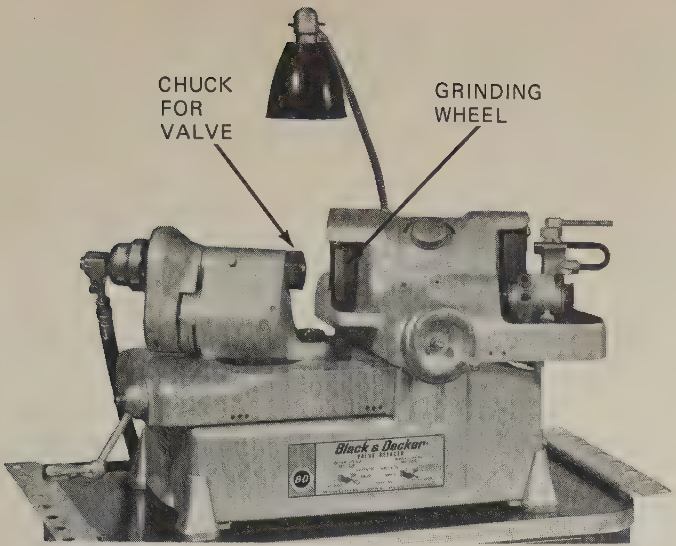


FIG. 32-22 Valve-refacing machine, also called a valve grinder. (*Black and Decker Manufacturing Company*)

machine. Move the lever to carry the valve face across the grinding wheel. The first cut should be a light one. If this cut removes metal from only one-half or one-third of the face, the valve may not be centered in the chuck. Or the valve stem may be bent, in which case the valve should be discarded. Cuts, after the first one, should remove only enough metal to true up the surface and remove pits. Do not take heavy cuts. If so much metal must be removed that the margin is lost, as shown in Fig. 32-20, discard the valve. Loss of the margin causes the valve to run hot and soon to fail.

If new valves are required, they will not need to be refaced. Seating should be checked, however. Never reface or lap coated valves.

Follow the operating instructions of the refacer manufacturer. In particular, dress the grinding wheel as necessary with the diamond-tipped dressing tool as shown in Fig. 32-23. As the diamond is moved across the rotating face of the grinding wheel, it cleans and aligns the grinding face.

FIG. 32-23 Using a diamond-tipped dressing tool to dress the valve-grinding wheel. (*Snap-on Tools Corporation*)

○ 32-13 REFACING VALVE-STEM TIPS If the tip of a valve stem is rough or worn unevenly, it can be ground lightly. Use the special attachment furnished with the valve-refacing machine as shown in Fig. 32-24. The attachment allows you to swing the valve slightly and rotate it. In this way, the tip can be ground to produce a slightly crowned, or rounded, end. One recommendation is to grind off as much from the stem as you ground off the valve face. In that way, you make up for the amount the valve sinks into the seat as a result of face grinding.

The ends of some valve stems are hardened. These should have no more than a few thousandths of an inch ground off them. Excessive grinding exposes soft metal, causing the stem to wear rapidly in the engine.

As the valves are refaced and cleaned, they should be returned to the valve rack. They are now ready for installation. First, however, the valve guides and valve seats must be serviced. Also, the other components of the valve train must be checked and serviced as necessary.

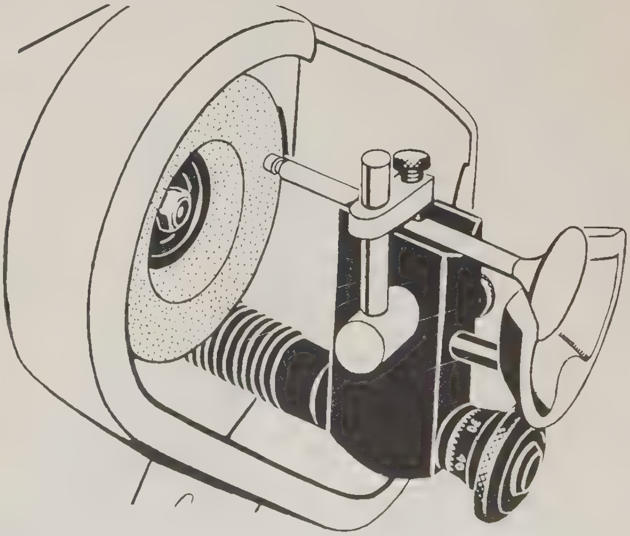


FIG. 32-24 Grinding the tip-end of a valve stem. (*Snap-on Tools Corporation*)

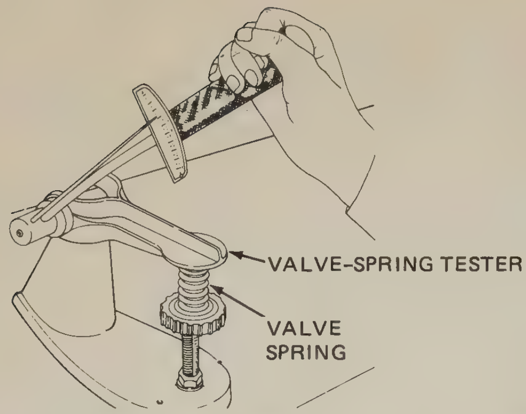


FIG. 32-25 Checking valve-spring tension. (*Outboard Marine Corporation*)

○ 32-14 CHECKING VALVE SPRINGS AND TAPPETS Valve springs should be tested for proper tension and for squareness. A valve-spring tester, shown in Fig. 32-25, is required to check spring tension. The pressure required to compress the spring to the proper length should be measured. Then the spring should be checked for squareness, as shown in Fig. 32-26. Stand the spring on a surface plate and hold a steel square next to it. Rotate the spring slowly against the square and see whether the top coil moves away from the square. If the spring is excessively out of square or lacks sufficient tension, discard it.

Check the valve-tappet faces which ride on the cams for roughness or wear. Check for wear also the adjusting-screw head which is in contact with the valve stem. If the tappets do not have adjusting screws, check the stem end of the tappets. If you find wear or roughness, new tappets will be required. The camshaft must be removed to remove the tappets, as explained later.

○ 32-15 SERVICING VALVE GUIDES The valve guide must be clean and in good condition for normal valve seating. It must be serviced before the valve seats are ground if grinding is required. As a first step, the valve guide should be cleaned with a wire brush or adjustable-blade cleaner. Then it should be checked for wear. If it is worn, it requires service. The type of service depends on whether the guide is replaceable or integral. If it is replaceable, the old guide should be pressed out. Then a new guide should be installed and reamed to size. If the guide is integral, you can service it in either of two ways: (1) by reaming it to a larger size and installing a valve with an oversize stem or (2) by knurling and reaming it.

The valve guide may wear bell-mouthed or oval-shaped, because the valve tends to wobble as it opens and closes. The bell-mouth wear shown in Fig. 32-27 is exaggerated. A small-hole gauge, shown in Fig. 32-27, will detect oval or bell-mouth wear. It is used as shown. The split ball is adjusted until it is a light drag fit at the point being checked. Then the split ball is measured with a micrometer. By checking the guide at various points, any eccentricity will be detected.

If the guide is worn, it should be rebushed, as

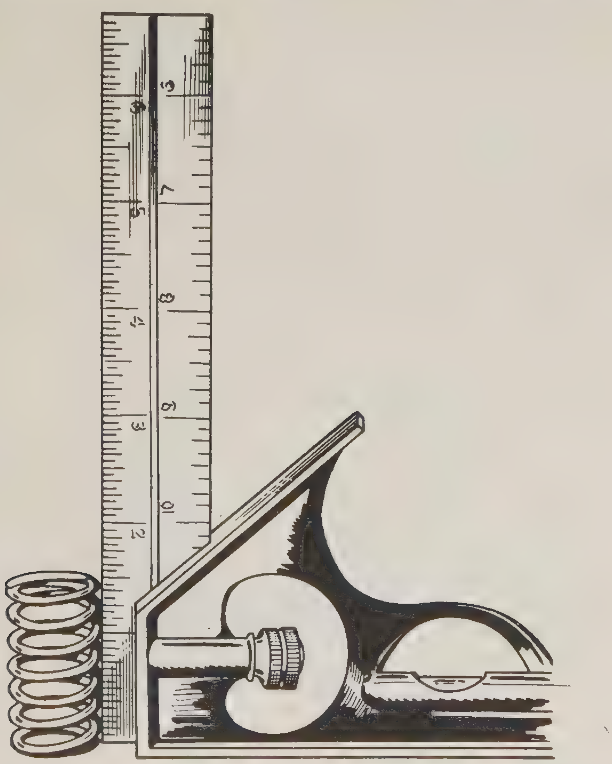


FIG. 32-26 Checking valve-spring squareness. (*Onan Corporation*)

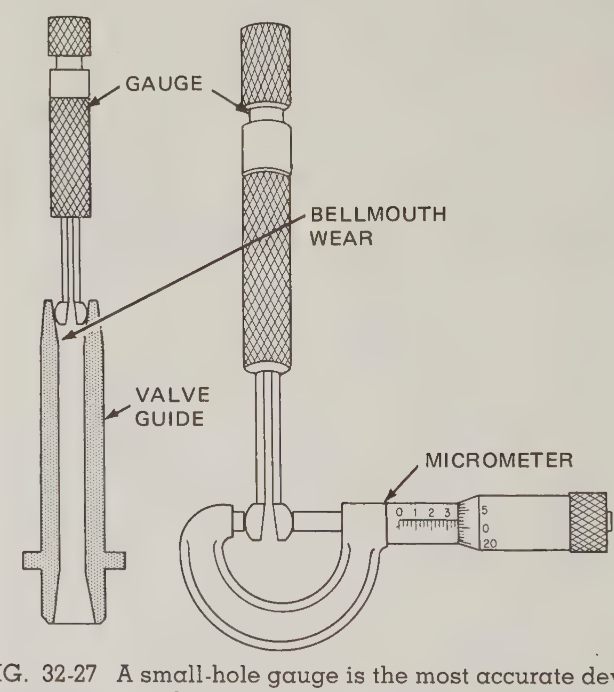


FIG. 32-27 A small-hole gauge is the most accurate device for inspecting valve-guide wear. The gauge is adjusted so that the split ball is a drag fit in the guide (left). Then the split ball can be measured with a micrometer (right).

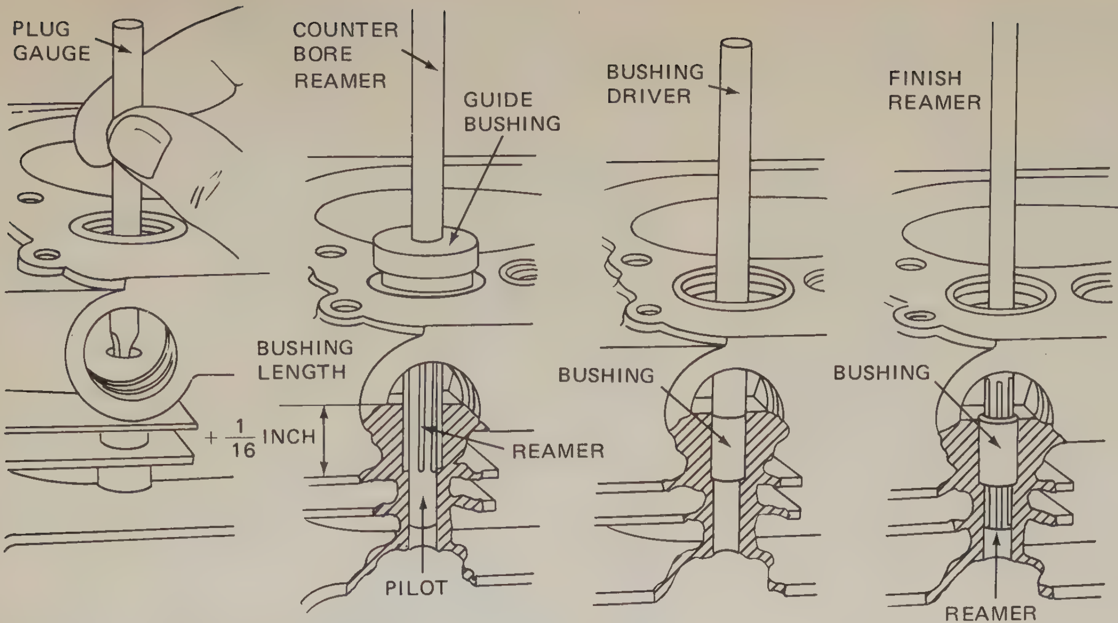


FIG. 32-28 Checking, installing, and reaming valve guides. (*Briggs & Stratton Corporation*)

shown in Fig. 32-28. First, a bushing guide is used to center the reamer, and then the reamer is turned to ream out the worn guide. Ream to only $^1/_{16}$ inch [1.59 mm] deeper than the valve-guide bushing. Then, after cleaning out all cuttings, press in a new valve-guide bushing, using a soft-metal driver of brass or copper to avoid peening over the top end of the bushing. Finally, finish reaming the new bushing to the proper size so that a standard valve can be used.

To remove the replaceable type of valve guide on some L-head engines, the guide is driven down into the valve-spring compartment.

New valve guides can be installed with a special driver or arbor press. Valve guides must be installed to the proper depth in the block or head. Then they must be reamed to size. This is usually done in two steps: a rough ream and then a second, or final, finishing ream. Figure 32-28 illustrates both the depth of assembly of valve guides and the reaming dimensions on one engine.

○ 32-16 GRINDING VALVE SEATS Valve seats are of two types. The integral type is actually the cylinder block or head. The insert type is a ring or insert of special metal set into the block or head. Grinding valve seats is described below. Replacing valve-seat inserts is covered in ○ 32-17.

If the valve seat is worn, burned, pitted, or otherwise damaged, it should be ground with a valve-seat grinder. If the seat is so badly worn or burned that it will not clean up, it is possible to counterbore the seat and install a seat insert.

As a first step in grinding a valve seat, make sure that the valve guide is in good condition. The reason

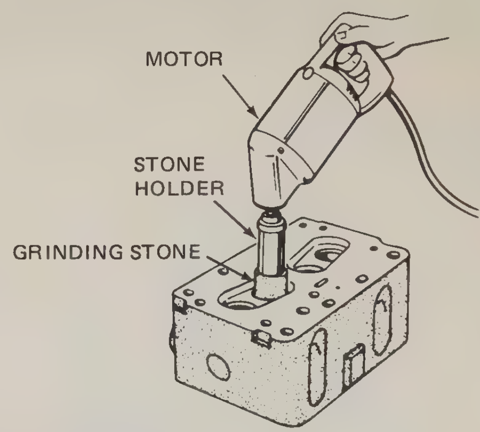


FIG. 32-29 Grinding a valve seat. (*The J. I. Case Company*)

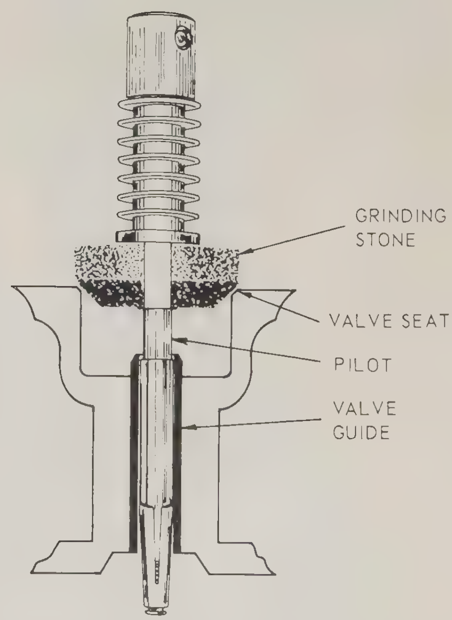


FIG. 32-30 Pilot on which the grinding stone rotates. The pilot keeps the stone concentric with the valve seat. (*Black and Decker Manufacturing Company*)

for this is that the seat-grinding stone is centered in the valve guide. We explained how to check and service valve guides in the previous section.

The valve-seat grinder rotates a grinding stone of the proper shape on the valve seat as shown in Fig. 32-29. The stone is kept concentric with the valve seat by a pilot installed in the valve guide as shown in Fig. 32-30. This means that the valve guide must be cleaned and serviced before the valve seat is ground. In the grinding set shown in Figs. 32-29 and 32-30, the stone is automatically lifted about once a revolution. This permits the stone to clear itself of grit and dust by centrifugal force.

Figure 32-30 shows how the seat-grinding stone is centered by means of a pilot installed temporarily in the valve guide. In operation, an electric or air-powered motor rotates the grinding stone and smooths the seat. The angle of the stone determines the angle to which the seat will be ground. This angle matches the angle to which the valve face is ground in the valve-face regrinder.

Be sure to follow the operating instructions furnished by the valve-seat-grinder manufacturer. The grinding stone must be dressed frequently with the diamond-tipped dressing tool as shown in Fig. 32-31.

After the valve seat is ground, it may be too wide. If so, it must be narrowed by having the upper and lower grinding stones grind away the upper and lower edges of the seat. A typical valve seat is shown in Fig. 32-20. A steel scale can be used to measure the valve-seat width.

Many small-engine manufacturers recommend that after the valve and valve seat are ground, the two should be lapped together to check and perfect the fit. Lapping compound is an abrasive paste that comes in a tube or small can. To use it, place a small amount on your finger. Then apply the lapping compound to the valve face as shown in Fig. 32-32. When there is a light coat of lapping compound around the entire valve face, place the valve in its proper guide.

To lap the valve, a lapping tool is used. It is a stick with a small rubber suction cup on one end which holds to the valve head. The lapping tool is rotated back and forth between your hands several times. The motion also causes the valve to lightly bounce up

Fig. 32-31 Using a diamond-tipped dressing tool to dress the valve-grinding wheel. *(Snap-on Tools Corporation)*

FIG. 32-32 Applying lapping compound to the valve face (*TRW, Inc.*)

FIG. 32-34 Lapping compound shows the valve has the correct valve-seat to valve-face contact area.

and down. This operation is shown in Fig. 32-33. Remove the valve from the guide, and wipe the valve face clean with a cloth. Figure 32-34 shows the proper valve face-valve seat contact area that you should see on every valve face. After the lapping operation is completed, the valve seat and valve must be thoroughly cleaned to remove all traces of lapping compound.

○ 32-17 VALVE-SEAT INSERTS Some engines are made with valve-seat inserts. These are metal rings that are set into the cylinder block or head to serve as the valve seats. They are made of special metal which can withstand the pounding and high temperatures valve seats are subjected to. If a valve-seat insert is worn so much that it cannot take another seat-grind job, or if it is cracked or burned, then a new insert can be installed. Also, some engine manufacturers supply information and tools that permit you to install seat inserts on engines that did not originally have them. We cover these procedures in this section.

Figures 32-35 and 32-36 show how to install the counterbore cutter. Figure 32-37 shows the counterboring procedure. If a worn valve-seat insert must be

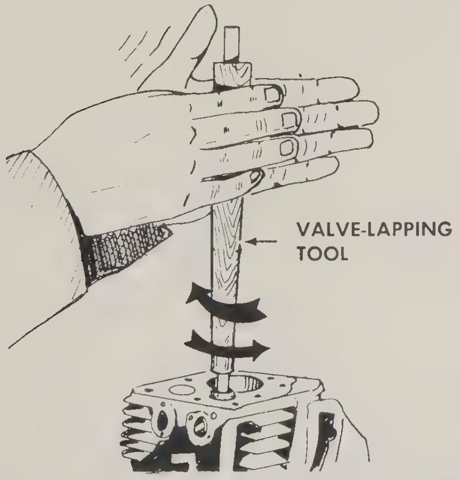


FIG. 32-33 Using a valve-lapping tool to improve fit of valve to seat.

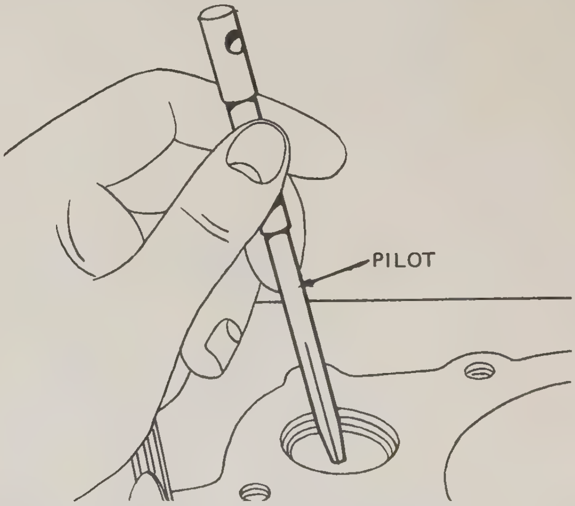


FIG. 32-35 Inserting pilot in preparation for counterboring for a valve-seat insert. (*Briggs & Stratton Corporation*)

FIG. 32-36 Inserting cutter shank in cutter. (*Briggs & Stratton Corporation*)

replaced, the old insert must be pulled with a special tool. This operation is shown in Figs. 32-38 and 32-39. Turning the bolt on the tool will pull out the old insert.

To install a new valve seat, the proper pilot must be used, along with the correct driver. Insert the pilot into the valve guide. Then drive the insert into place with the driver, as shown in Fig. 32-40. The new

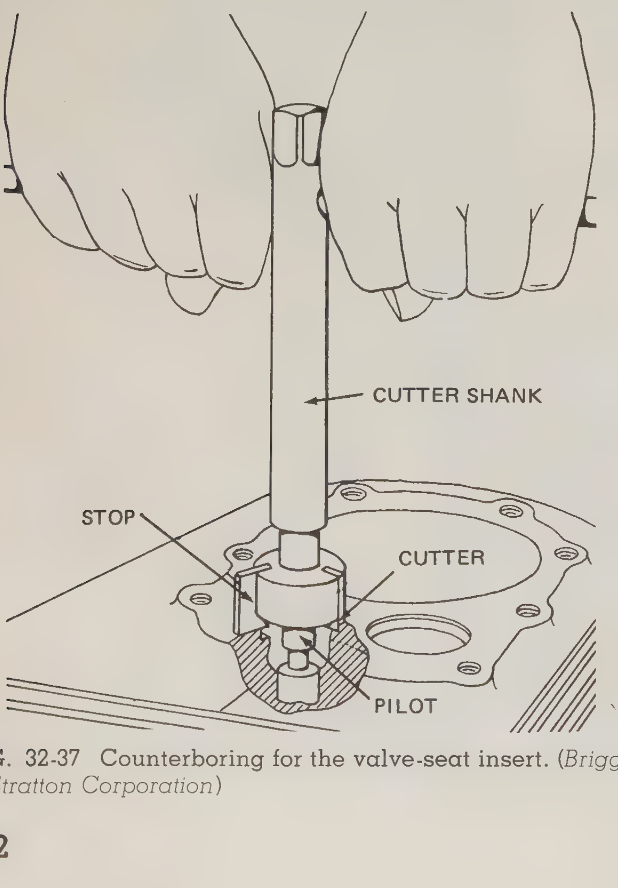


FIG. 32-37 Counterboring for the valve-seat insert. (*Briggs & Stratton Corporation*)

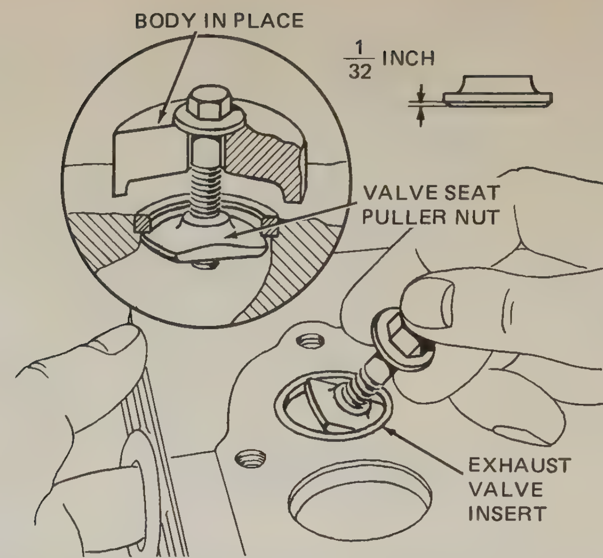


FIG. 32-38 Inserting the valve-seat-insert puller. (*Briggs & Stratton Corporation*)

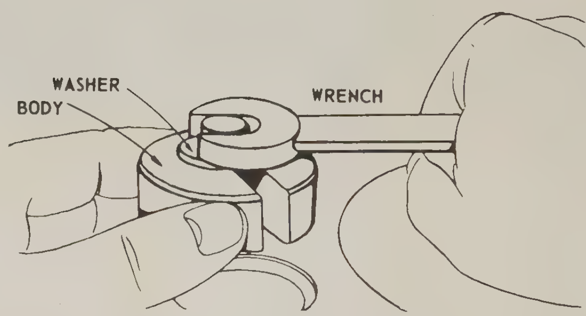


FIG. 32-39 Pulling the valve-seat insert. (*Briggs & Stratton Corporation*)

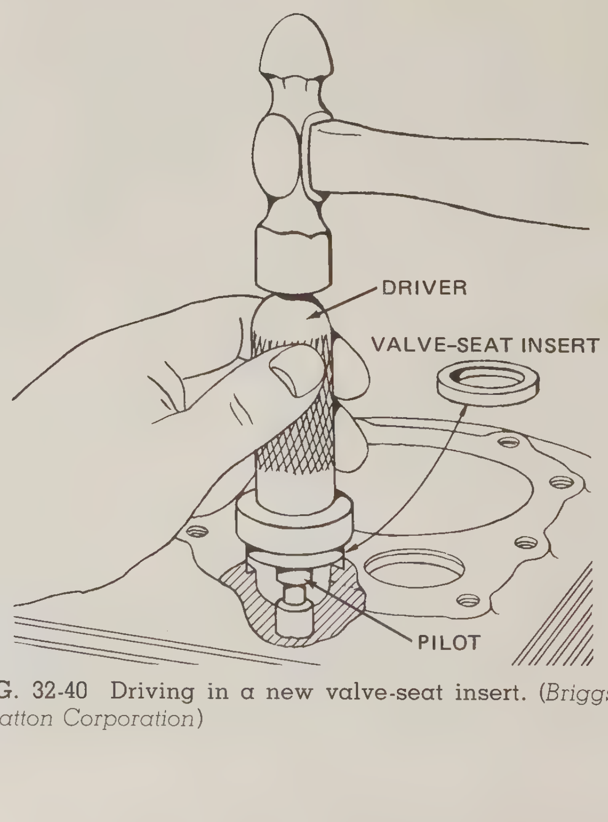


FIG. 32-40 Driving in a new valve-seat insert. (*Briggs & Stratton Corporation*)

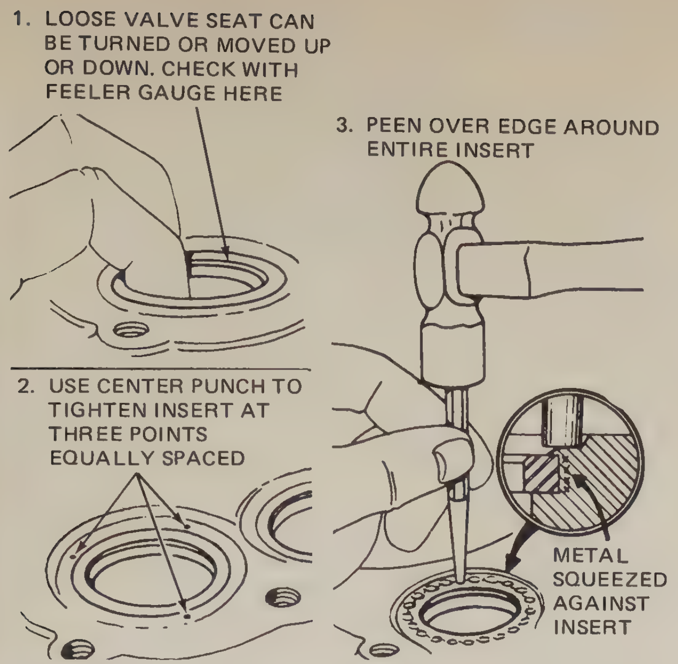


FIG. 32-41 Peening around the edge of the valve-seat insert to hold it in position. (*Briggs & Stratton Corporation*)

valve-seat insert should be ground lightly. Then lap the valve into the seat with lapping compound. This procedure was covered earlier. On aluminum blocks, peen around the insert to help lock it in place, as shown in Fig. 32-41. However, if a 0.005-inch [0.13-mm] feeler gauge will fit in the space between the insert and the cylinder, the cylinder must be replaced.

○ 32-18 CAMSHAFT SERVICE In addition to having a pair of cams to operate the valves, camshafts also may have an eccentric to operate the oil pump. The action of the oil pump is discussed in an earlier chapter. Some camshafts also include an automatic-compression-release device. This also was covered in a previous chapter. Some Kohler engines have the ignition breaker-point cam on the camshaft mounted through a centrifugal-advance mechanism. This provides an ignition retard during cranking so as to avoid kickback. After the engine starts, the ignition advances to the running position. Later engines, using the automatic compression release, do not use this ignition-advance mechanism. Some engines have a power takeoff on the camshaft. Some engines also have a governor drive gear which drives an internal centrifugal governor. As you can see, there are a variety of camshaft-driven mechanisms on four-cycle engines.

If the camshaft or bearings appear to be worn, then you should remove the camshaft for inspection. The removal procedure varies according to the engine design. On many engines, take off the baseplate or gear cover and lift out the camshaft as shown in Fig. 32-42. Be sure to find the timing marks on the

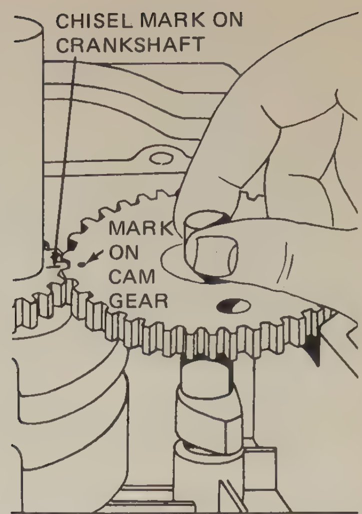


FIG. 32-42 Lifting camshaft out of the engine. (*Briggs & Stratton Corporation*)

camshaft and crankshaft gears. These can be center-punch or chisel marks. Some engines have a chamfer on the end of one crankshaft-gear tooth. These marks must be aligned when the camshaft is reinstalled to assure proper valve timing. On some engines, you must remove the crankshaft first, before you can remove the camshaft. Also, some engines have thrust bearing that must be removed when you remove the camshaft.

Before attempting to remove the camshaft, turn it until the timing marks align on the compression stroke. In this position, both valves are closed and the valve tappets are free of the camshaft. This makes it easy to slip the camshaft out. Turn the engine on its side so the tappets will not fall out. Some engines using ball bearings require removal of the camshaft and crankshaft together. Also, some engines have the camshaft supported on a pin which must be driven out before the camshaft can be removed. If the camshaft has an end-play washer, carefully note its position. Then remove it. During engine assembly, the washer must be reinstalled in its original position. Wash the camshaft with solvent to clean off dirt and oil. Check the gears for wear or nicks. Check the automatic compression release or ignition-advance mechanism (Fig. 32-43) for freedom of action. If the camshaft has oil holes, blow them out with compressed air.

Figure 32-44 shows the various points at which the camshaft should be inspected. The camshaft dimensions, arrowed in Fig. 32-44, should be checked with a micrometer. Compare the measurements with the manufacturer's specifications. Discard the camshaft if the wear is excessive.

Normal cam wear is close to the center of the cam. The reason for this is that the cam is slightly tapered in many engines. Also, the tappet foot may be slightly spherical or crowned in shape. Therefore, when all is well, the contact pattern appears as a

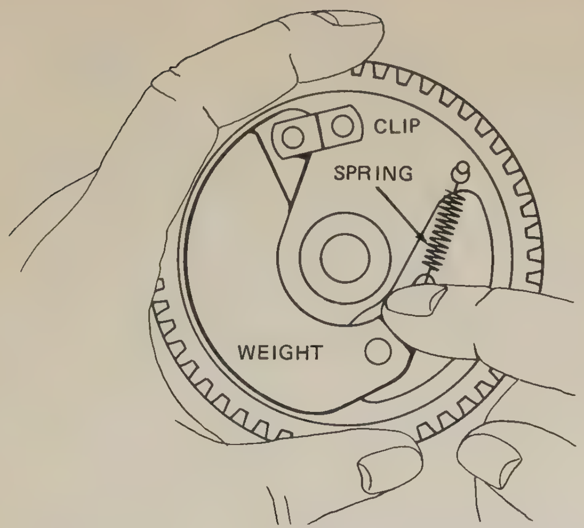


FIG. 32-43 Checking automatic spark advance on the camshaft gear for freeness of action. (*Briggs & Stratton Corporation*)

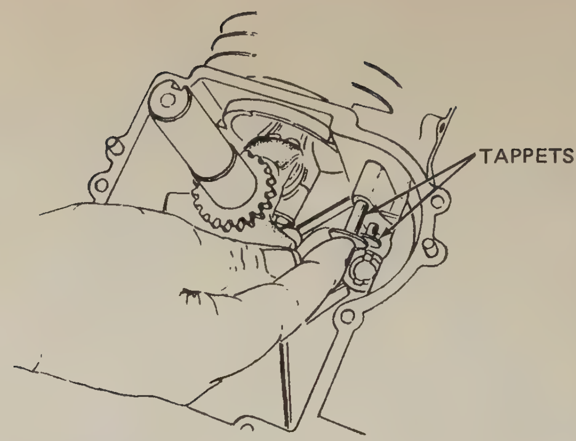


FIG. 32-45 Installing valve tappets in the engine. (*Clinton Engines Corporation*)

narrow band around the cam lobe. If wear shows across the full width of the cam, a new camshaft is required. The tappet should also be checked. Remove the tappets and examine them for wear. An excessively worn tappet must be replaced. If it is only slightly worn or pitted, it can often be reground on a valve-refacing machine and reused. A slight crown on the foot of the tappet can be produced by rocking and rotating the tappet during the finish grind.

Cam-lobe lift can be checked with the camshaft in or out of the engine. A dial indicator is needed to make the check with the camshaft in the engine. To measure lobe lift with the camshaft out of the engine, use a micrometer. Measure from the nose of the cam to the back of the cam. Then make another measurement at a right angle to the first measurement. Cam-lobe lift is the difference between these two measurements.

If the camshaft rides in sleeve bearings, or bushings, check them for wear and replace them if necessary. Replacement requires special drivers to force the old bushings out and new bushings in. Then the new bushings must be reamed to size. If the camshaft is supported by ball or roller bearings, check them as explained earlier in this lesson.

To install the camshaft, first install the tappets as shown in Fig. 32-45. Make sure you put the tappets back in the same holes from which you took them. If you get the tappets reversed, they may not fit properly. On some engines, the two tappets are of different lengths.

Push the tappets up out of the way, and then install the camshaft (Fig. 32-46). If the camshaft is supported by a camshaft pin, put the camshaft and crankshaft in first. Then align the timing marks before positioning the camshaft and driving the camshaft pin into place.

On all four-cycle engines, always be sure the timing marks are properly aligned when installing the camshaft and crankshaft. This is essential for correct valve timing. If the camshaft has additional parts attached, such as the oil pump, governor drive gear, ignition centrifugal-advance mechanism, or automatic compression release, make sure they are properly aligned. Put a little oil on all parts—tappets,

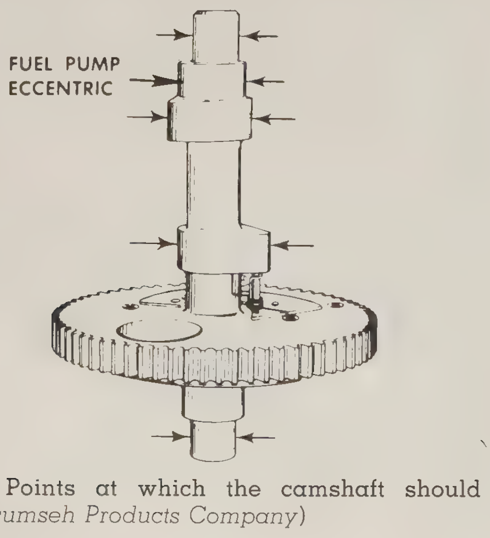


FIG. 32-44 Points at which the camshaft should be checked. *Tecumseh Products Company*)

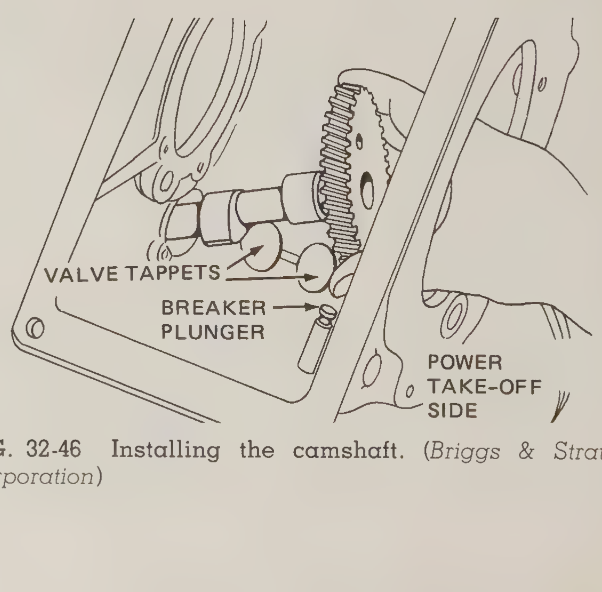


FIG. 32-46 Installing the camshaft. (*Briggs & Stratton Corporation*)

bushings, camshaft, advance or compression release—before final installation.

○ 32-19 ENGINE REASSEMBLY Now you are ready to install the valves and reassemble the engine. On engines with solid or nonadjustable valve tappets, install the valves in their proper positions in the cylinder block. Turn the crankshaft until one of the valves is in its highest position. Then turn the crankshaft one more complete revolution. Check the clearance with a feeler gauge. Repeat for the other valve. If the clearance is too small, as it may be if valves and seats have been ground, grind off the end of the valve stem, as necessary, to get the correct clearance.

Some valve tappets have an adjusting screw. On these, you can adjust the valve-tappet clearance by turning the screw in or out, as shown in Fig. 11-2. We discussed checking and adjusting valve-tappet clearance earlier in this chapter.

○ 32-20 INSTALLING VALVES Check the valve springs carefully before installing the valves. If the spring is held in place by a pin or a split collar, put the spring with the retainer in the spring compressor, as shown in Fig. 32-47. Insert the compressor with spring and retainer into position in the cylinder block, and then drop the valve into place. Install the retainer pin or collar and release the spring pressure. Pull out the compressor. On the one-piece retainer, move the retainer around when dropping the valve into place so the stem enters the larger part of the opening, allowing the stem to go through. Then lift the retainer up and center it in the undercut on the valve stem. Now release the spring pressure and remove the spring compressor.

○ 32-21 INSTALLING THE CYLINDER HEAD When installing the cylinder head, use a new head gasket. Do not use any sealer on the gasket. Use graphite grease on screws that go into aluminum cylinders. Tighten the screws down evenly by hand, and then use a torque wrench to finish the job. Tighten the screws in the sequence and to the torque shown in the manufacturer's specifications.

Do not tighten the screws down to the total torque the first time you put the wrench on them. Instead, tighten each screw in sequence only a little. Go around again and a third or fourth time, tightening the screws a little more each time until finally all are at the proper tightness. This assures even tension on all screws and guards against a warped cylinder head.

REVIEW QUESTIONS

1. What is the biggest difference between servicing a two-cycle engine and servicing a four-cycle engine?
2. What is a short block?
3. What is a miniblock?
4. On what type of engine repair would you use a short block?
5. Describe the procedure to adjust the valves on an L-head engine.
6. How are valve adjustments made on overhead-valve engines with hydraulic valve lifters?
7. Describe the procedure to adjust the valves on an overhead camshaft engine that has the cam lobes operating directly on the valves.
8. How do you remove the mushroomed end of a valve stem so the valve can be removed?
9. Why should the cylinder head never be removed until after the engine has cooled?
10. What tool is used to compress valve springs so that the locks and retainers can be removed?
11. What is the margin of a valve?

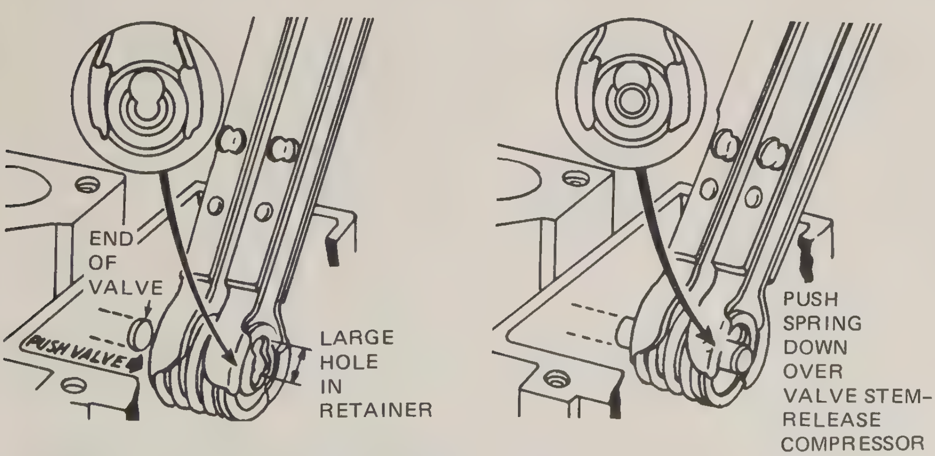


FIG. 32-47 Compressing valve spring in preparation for valve installation. (*Briggs & Stratton Corporation*)

12. During the use of the valve-refacing machine, what tool must be used periodically to ensure that the face of the grinding wheel is clean, straight, and smooth?

13. Explain how to service the tip end of the valve stem.

14. How are valve guides checked?

15. Why are valve guides serviced before the valve seats are refinished?

16. What are the two general types of valve guides?

17. What is the interference angle, as applied to valves and valve seats?

18. How do you lap a valve?

19. Describe the steps in removing and installing a new valve-seat insert.

20. Explain how to inspect a camshaft for wear and damage.

21. Why must the timing marks on the camshaft and crankshaft be aligned during installation of the camshaft?

22. Can a valve tappet be reused if it is dished in on the foot that rides against the cam lobe?

23. Describe the procedure to install new camshaft bearings.

24. What do you do if an insert type of bearing fits loosely in the bearing cap?

25. Where do you find the bolt-tightening sequence to use when installing the bolts in a cylinder head?

26. Should new valves be refaced on the valve-refacing machine before installation?

SELF PROJECTS

1. As you look through the junk box in the shop and as you do valve-service jobs on engines, save valves showing different kinds of troubles. Mount the valves on a board. Add a label under each, identifying the trouble.

2. Study valve-adjusting procedures in various manufacturers' shop manuals. Write short summaries on how the various manufacturers want the valves in their engines adjusted. File these in your notebook.

3. Study the instruction manuals for the valve grinder and valve-seat grinder. Prepare, for your notebook, brief notes on how to use these two machine tools.

GLOSSARY

This glossary of terms used in small-engine mechanics and employed in this book provides a ready reference for the student. The definitions may differ from those given in a standard dictionary. These definitions are not intended to be all-inclusive. They are meant to provide the practical meaning or meanings of importance and usefulness to the small-engine technician. More complete definitions and explanations of the terms usually are found in the text.

ABRASIVE A substance used for cutting, grinding, lapping or polishing metal.

ACCELERATOR PUMP In some carburetors, a pump, linked to the accelerator, which momentarily enriches the mixture when the accelerator pedal is depressed.

ADDITIVE A substance added to gasoline or oil which improves some property of the gasoline or oil.

ADJUST To bring the parts of a component or system to a specified relationship, dimension, or pressure.

AIR CLEANER A device mounted on the carburetor for filtering out dirt and dust from air being drawn into the engine.

AIR-COOLED ENGINE An engine that is cooled by the passage of air around the cylinders, not by passage of a liquid through water jackets.

AIR-FUEL MIXTURE Name given to the air and fuel traveling to the combustion chamber after being mixed by the carburetor.

AIR GAP A small space between parts that are related magnetically, as in an alternator, or electrically, as the electrodes of a spark plug.

AIR HORN In the carburetor, the tubular passage through which the incoming air must pass.

AIR PRESSURE Atmospheric pressure of 14.7 psi (pounds per square inch) or, in the metric system, 1.0355 kg/cm^2 (kilograms per square centimeter) at sea level; or the pressure of air produced by pump, by compression in engine cylinder, etc.

ALTERNATOR The device in the electric system that converts mechanical energy into electrical energy for charging the battery, etc. Also known as an ac generator, the alternator produces alternating current, which must be changed to direct current for use in the engine.

ALUMINUM CYLINDER BLOCK An engine cylinder block cast from aluminum or aluminum alloy and usually provided with cast-iron sleeves for use as cylinder bores.

ANTIFRICTION BEARING Name given to almost any type of ball, roller, or tapered roller bearing.

ANTIKNOCK COMPOUND An additive put into gasoline to suppress spark knock or detonation.

ARBOR PRESS Small hand-operated press used on jobs when light pressure is needed.

ATDC After top dead center.

ATMOSPHERIC PRESSURE See "Air pressure."

BACKFIRING Pre-explosion of air-fuel mixture so that the explosion passes the open intake valve and flashes back through the intake manifold; also, the loud explosion of overly rich exhaust gas in the exhaust manifold.

BACKLASH In gearing, the clearance between meshing teeth of two gears. Generally, the amount of free motion, or lash, in a mechanical system; the amount by which the width of the tooth space exceeds the thickness of the tooth in that space.

BACK PRESSURE Pressure in the exhaust manifold: the higher the back pressure, the lower the volumetric efficiency.

BATTERY An electrochemical device for storing energy in chemical form so that it can be released as electricity. A group of electric cells connected together.

BDC Bottom dead center.

BEARING The part which transmits the load to the support and, in so doing, takes the friction caused by moving parts in contact.

BEARING CAPS In the engine, caps held in place by bolts or nuts which, in turn, hold bearing halves in place.

BEARING CRUSH The additional height over a full half which is purposely manufactured into each bearing half. This ensures complete contact of the bearing back with the housing bore when the engine is assembled.

BEARING OIL CLEARANCE The space purposely provided between the shaft and the bearing through which lubricating oil can flow.

BEARING SPIN A type of bearing failure caused by lack of lubrication which overheats the bearing until it seizes on the shaft, shearing the locking lip and causing the bearing to rotate in the housing or block.

BEARING SPREAD A purposely manufactured small extra distance across the parting faces of the bearing half in excess of the actual diameter of the housing bore.

BELL-SHAPED WEAR Deterioration of an opening (such as a valve guide) in which one end is worn most, causing the opening to flare out like a bell.

bhp See "Brake horsepower."

BIG END The crankpin end of the connecting rod.

BLOCK See "Cylinder block."

BLOW-BY Leakage of unburned air-fuel mixture and some burned gases past the piston rings into the crankcase during the compression and combustion strokes.

BORE The diameter of an engine cylinder; the diameter of any hole. Also used to describe the process of enlarging, or accurately refinishing, a hole, as "to *bore* an engine cylinder."

BORING BAR An electric-motor-powered cutting tool used to machine, or bore, engine cylinders, thereby removing metal and enlarging the cylinder's bore.

BOTTOM DEAD CENTER (BDC) The piston position when the piston has moved to the bottom of the cylinder and the cylinder volume is at its maximum.

BRAKE HORSEPOWER (bhp) The power delivered by the engine which is available for doing work.

BREAKER POINTS See "Contact points."

BREATHER The opening used on engines without emission-control devices that allow air to circulate through the crankcase and thus produce crankcase ventilation.

BTDC Before top dead center.

BURR A featheredge of metal left on a part being cut with a file or other cutting tool.

BUSHING A one-piece sleeve placed in a bore to serve as a bearing surface.

CAM A rotating lobe or eccentric which changes rotary motion to reciprocating motion.

CAM-GROUND PISTON A piston that is ground slightly oval in shape. It becomes round as it expands with heat.

CAMSHAFT The shaft in the engine which has a series of cams for operating the valve mechanisms. It is driven by gears or sprockets and chain from the crankshaft.

CAPACITOR See "Condenser."

CARBON A black deposit left on engine parts by the combustion of fuel. Carbon forms on pistons, rings, valves, etc., inhibiting their action.

CARBON DIOXIDE (CO_2) A colorless, odorless gas which results when gasoline is burned completely.

CARBON MONOXIDE (CO) A colorless, odorless, tasteless, poisonous gas which results when gasoline is burned incompletely.

CARBURETOR The mixing device in the fuel system which meters gasoline into the air stream (vaporizing the gasoline as it does so) in varying proportions to suit engine operating conditions.

CELSIUS In the metric system, a temperature scale on which water boils at 100° and freezes at 0°; equal to a reading on a Fahrenheit thermometer of $^5/_9$ (°F − 32). Also called centigrade.

CENTIGRADE See "Celsius."

CENTIMETER (CM) A unit of linear measure in the metric system equal to approximately 0.39 inch.

CHOKE In the carburetor, a device used when starting a cold engine that chokes off the air flow through the air horn, producing a partial vacuum in the air horn for greater fuel delivery and a richer mixture.

CHROME-PLATED RING A piston ring that has its cylinder-wall face lightly plated with hard chrome.

CLEARANCE The space between two moving parts or between a moving and a stationary part, such as a journal and a bearing. Bearing clearance is considered to be filled with lubricating oil when the mechanism is running.

CLOSED-CRANKCASE VENTILATING SYSTEM A system in which the crankcase vapors (blow-by gases) are discharged into the engine intake system and pass through the engine cylinders rather than being discharged into the air.

CLUTCH In the vehicle, the mechanism in the power train that connects the engine crankshaft to, or disconnects it from, the transmission and the remainder of the power train.

CO Chemical formula for carbon monoxide.

CO_2 Chemical formula for carbon dioxide.

COATED RING A piston ring having its cylinder-wall face coated with ferrous oxide, soft phosphate, or tin. This thin coating helps new rings seat by retaining oil and reducing scuffing during break-in.

COIL SPRING A spring made up of an elastic metal, such as steel, formed into a wire or bar and wound into a coil.

COMBUSTION Burning; in the engine, the rapid burning of the air-fuel mixture in the cylinder.

COMBUSTION CHAMBER The space at the top of the cylinder and in the head in which combustion of the air-fuel mixture takes place.

COMPRESSION RATIO The ratio between the volume in the cylinder with the piston at BDC and the volume with the piston at TDC.

COMPRESSION RINGS The upper ring or rings on a piston designed to hold the compression in the cylinder and prevent blow-by.

COMPRESSION STROKE The piston stroke from BDC to TDC during which both valves are closed and the air-fuel mixture is compressed.

COMPRESSION TESTER A gauge for measuring the pressure, or compression, developed in an engine cylinder during cranking.

CONDENSER In the ignition system, a device that also is called a capacitor. It is connected across the breaker points to reduce arcing by providing a storage place for electricity (electrons) as the breaker points open.

CONNECTING ROD In the engine, the rod that connects the crank on the crankshaft with the piston.

CONNECTING-ROD BEARINGS See "Rod bearings."

CONNECTING-ROD CAP The part of the connecting-rod assembly that attaches the rod to the crankpin.

CONTACT POINTS In the breaker-point ignition system, the stationary and the movable points which open and close the ignition primary circuit.

COOLANT The liquid mixture of antifreeze and water used in the liquid cooling system.

COOLING SYSTEM In the engine the system that removes heat by the circulation of liquid coolant or of air to prevent engine overheating.

COUNTERBORED RING A piston ring, used as a compression ring, which has a counterbore on its inside diameter to promote cylinder sealing.

CRANK A device for converting reciprocating motion into rotary motion, or vice versa.

CRANKCASE The lower part of the engine in which the crankshaft rotates. The upper part of the crankcase is the lower section of the cylinder block, and the lower part is made up of the oil pan.

CRANKCASE DILUTION Dilution of the lubricating oil in the oil pan by liquid gasoline seeping down the cylinder walls.

CRANKCASE VENTILATING SYSTEM The system that permits air to flow through the engine crankcase when the engine is running to carry out the blow-by gases and relieve any pressure buildup.

CRANKING MOTOR See "Starting motor."

CRANKPIN That part of a crankshaft to which the connecting rod is attached.

CRANKPIN RIDGING A type of crankpin failure typified by deep ridges worn into the crankpin bearing surfaces.

CRANKSHAFT The main rotating member, or shaft, of the engine with cranks to which the connecting rods are attached.

CRANKSHAFT GEAR A gear, or sprocket, mounted on the front of the crankshaft used to drive the camshaft gear, or chain.

CROSS-FIRING In a multicylinder engine, jumping of high-voltage surge in the ignition secondary circuit to the wrong high-voltage lead so that the wrong spark plug fires. Usually caused by improper routing of the spark-plug wires, by faulty insulation, or by a defective distributor cap or rotor.

CUBIC CENTIMETER (cc) A unit in the metric system used to measure volume; equal to approximately 0.061 cubic inch.

CYCLE Any series of events which continuously repeat. In the engine, the four piston strokes (or two piston strokes) that complete the working process and produce power.

CYLINDER A round hole or tubular-shaped structure in a block or casting in which a piston reciprocates. In an engine, the circular bore in the block in which the piston moves up and down.

CYLINDER BLOCK The basic framework of the engine in and on which the other engine parts are attached. It includes the engine cylinders and the upper part of the crankcase.

CYLINDER BORING MACHINE See "Boring bar."

CYLINDER COMPRESSION See "Compression tester."

CYLINDER HEAD The part that encloses the cylinder bores. It contains the valves on I-head engines.

CYLINDER HONE An expandable rotating tool with abrasive fingers turned by an electric motor, used to clean and smooth the inside surface of a cylinder.

CYLINDER LINER See "Cylinder sleeves."

CYLINDER SLEEVES A replaceable sleeve, or liner, inset into the cylinder block to form the cylinder bore.

DEGREE (of a circle) $^1/_{360}$ of the circumference of a circle.

DETERGENT A chemical added to engine oil designed to help keep the internal parts of the engine clean by preventing the accumulation of deposits.

DETONATION In the engine, an uncontrolled second explosion after the spark occurs, with excessively rapid burning of the compressed air-fuel mixture, resulting in a spark knock, or pinging noise.

DIAL INDICATOR A gauge that has a dial face and a needle to register movement; used to measure variations in size, movements too little to be measured conveniently by other means, etc.

DIE A special tool for cutting threads on a rod.

DIESEL CYCLE An engine cycle of events in which air alone is compressed and fuel oil is injected at the end of the compression stroke. The heat produced by compressing the air ignites the fuel oil, eliminating the need for spark plugs or a separate ignition system.

DIESEL ENGINE An engine that operates on the diesel cycle and burns oil instead of gasoline.

DIESELING A condition in which an engine continues to run after the ignition is shut off.

DIODE A solid-state electronic device that allows the passage of an electric current in one direction only. Used in the charging system to convert alternating current to direct current for charging the battery.

DIPSTICK The oil-level indicator stick.

DIRECT-BONDED BEARING A bearing formed by pouring babbitt (bearing metal) directly into the bearing housing, and the machining of the desired size bearing diameter in that cast metal.

DISASSEMBLE To take apart.

DISPERSANT A chemical added to oil to prevent dirt and impurities clinging together in lumps that clog the engine lubricating system.

DISPLACEMENT In an engine, the total volume of air-fuel mixture an engine is theoretically capable of drawing into all cylinders during one operating cycle. The space swept through by the piston in moving from one end of a stroke to the other.

DOHC ENGINE Engine with double, or two, camshafts over each line of cylinders.

DRILL Also called twist drill. A cylindrical bar with helical grooves and a point for cutting holes in material. Also refers to the device that rotates the drill.

DRIVE PINION A gear or a rotating shaft that transmits torque to another gear.

DRY FRICTION The friction between two dry solids.

DYNAMOMETER A device for measuring the power output or brake horsepower, of an engine; may be an engine dynamometer, which measures power output at the flywheel, or a chassis dynamometer, which measures the power output at the drive wheels.

ECCENTRIC A disk or offset section—of a shaft, for example—used to convert rotary to reciprocating motion.

EFFICIENCY The ratio between the effect produced and the power expended to produce the effect; the ratio between the actual and the theoretical.

ELECTRIC SYSTEM The system that electrically cranks the engine for starting, furnishes high voltage sparks to the engine cylinders to fire the compressed air-fuel charges, lights the lights, and operates the other electrical equipment. It consists, in part, of the starting motor, wiring battery, alternator, regulator, ignition distributor, and ignition coil.

ELECTROLYTE The mixture of sulfuric acid and water used in lead-acid storage batteries. The acid enters into chemical reaction with active material in the plates to produce voltage and current.

ELECTRONIC IGNITION SYSTEM An ignition system using transistors which does not have mechanical contact points. Also called solid-state ignition.

EMISSION CONTROLS A term applied to any device, or modification, added onto, or designed into, an engine for the purpose of controlling a source of air-pollution emissions.

END PLAY As applied to the crankshaft, the amount that the crankshaft can move forward and back.

ENERGY The capacity or ability to do work.

ENGINE A machine that converts heat energy into mechanical energy. The assembly that burns fuel to produce power, sometimes referred to as the power plant.

ENGINE TUNEUP The procedure of checking and adjusting various engine components so that the engine is restored to top operating condition.

ETHYL See "Tetraethyl lead."

EVAPORATIVE EMISSION-CONTROL SYSTEM A system which prevents the escape of gasoline vapors from the fuel tank or carburetor float bowl to the atmosphere while the engine is off. The vapors are stored in a canister, or in the crankcase, until the engine is started.

EXHAUST-GAS ANALYZER A device for sampling the exhaust gas from an engine to determine the amounts of pollutants in the exhaust gas. Most analyzers used in the shop check HC and CO, while analyzers used in testing laboratories can also check NO_2.

EXHAUST MANIFOLD A housing with a series of connecting pipes between the exhaust ports and the exhaust pipe through which hot burned gases from the engine cylinders flow.

EXHAUST STROKE The piston stroke from BDC to TDC during which the exhaust valve is open so that the burned gases are forced from the cylinder.

EXHAUST VALVE The valve which opens to allow the burned gases to exhaust from the engine cylinder during the exhaust stroke.

EXPANSION PLUG A plug that is slightly dished out and used to seal core passages in the cylinder block and cylinder head. When driven into place, it is flattened and expanded to fit tightly.

EXPANSION TANK A tank at the top of an engine radiator which provides room for heated coolant to expand and give off any air that may be trapped in the coolant. Also used in some fuel tanks to prevent fuel spilling from the tank because of expansion.

FATIGUE FAILURE A type of metal failure resulting from repeated stress which finally alters the character of the metal so that it cracks. In engine bearings, frequently caused by excessive idling or slow engine idle speed.

FEELER GAUGE Strips of metal of accurately known thicknesses used to measure clearances.

FILTER That part in the lubricating or fuel system through which fuel, air, or oil must pass so that dust, dirt, or other contaminants are removed.

FINS Thin metal projections on an air-cooled engine cylinder and head which greatly increase the heat transferring surfaces and help provide cooling of the engine cylinder. In a radiator, the thin metal projections, over which cooling air flows, that carry heat away from the hot coolant passages to the passing air.

FIRING ORDER The order in which the engine cylinders fire, or deliver their power strokes, beginning with the No. 1 cylinder.

FLAT-HEAD ENGINE See "L-head engine."

FLOAT BOWL In the carburetor, the reservoir from which gasoline feeds into the passing air.

FLYWHEEL The rotating metal wheel attached to the crankshaft which helps even out the power surges from the power strokes and also may serve as part of the clutch and engine-cranking system.

FLYWHEEL RING GEAR The gear fitted around the flywheel that is engaged by the teeth on the starting-motor drive to crank the engine.

FOUR-CYCLE Short for "four-stroke-cycle."

FOUR-STROKE CYCLE The four piston strokes of intake, compression, power, and exhaust, which make up the complete cycle of events in the four-stroke-cycle engine.

FRICTION The resistance to motion between two bodies in contact with each other.

FRICTION BEARINGS Bearings having sliding contact between the moving surfaces. Sleeve bearings, such as those used in connecting rods, are friction bearings.

FRICTION HORSEPOWER (fhp) The power used up by an engine in overcoming its own internal friction; usually it increases as engine speed increases.

FUEL The substance that is burned to produce heat and create motion in an engine.

FUEL INJECTION A system replacing the conventional carburetor which delivers fuel under pressure into the combustion chamber or into the air flow just as it enters each individual cylinder.

FUEL NOZZLE The tube in the carburetor through which gasoline feeds from the float bowl into the passing air. In a fuel-injection system, the tube that delivers the fuel into the air.

FUEL PUMP The electrical or mechanical device in the fuel system which transfers fuel from the fuel tank to the carburetor.

FUEL SYSTEM In the engine, the system that delivers to the engine cylinders the combustible mixture of vaporized fuel and air. It consists of fuel tank, lines gauge, carburetor, fuel pump, and intake manifold.

FUEL TANK The storage tank for fuel on the engine.

GAS A state of matter, neither solid nor liquid, which has neither definite shape nor definite volume. Air is a mixture of several gases. In the engine, the discharge from the muffler is called the exhaust gas. "Gas" is a slang expression used for the liquid fuel gasoline.

GASKET A flat strip, usually of cork or metal, or both, placed between two machined surfaces to provide a tight seal between them.

GASKET CEMENT A liquid adhesive material, or sealer, used to apply gaskets; in some applications the liquid layer of gasket cement is used as the gasket.

GASOLINE A liquid blend of hydrocarbons, obtained from crude oil, used as the fuel for most engines.

GEAR RATIO The relative speeds at which two gears (or shafts) turn; the proportional rate of rotation.

GEARS Mechanical devices to transmit power, or turning effort, from one shaft to another; gears contain teeth that interlace, or mesh, as the gears turn.

GEAR-TYPE PUMP A pump using a pair of matching gears that rotate; meshing of the gears forces oil (or other liquid) from between the teeth through the pump outlet.

GENERATOR A device that converts mechanical energy into electrical energy; it can produce either ac or dc electricity. In general usage, the term applies to a dc generator.

GLAZE The mirrorlike, very smooth finish that develops on engine cylinder walls.

GLAZE BREAKER A tool, rotated by an electric motor, used to remove the glaze from engine cylinder walls.

GOGGLES Special glasses worn over the eyes to protect them from flying chips, dirt, or dust.

GOVERNOR A device that governs or controls another device, usually in accordance with speed or rpm.

GREASY FRICTION The friction between two solids coated with a thin film of oil.

GRINDER A machine for removing metal by means of an abrasive wheel or stone.

GRINDING WHEEL A wheel made of abrasive material used for grinding metal objects held against it.

GROUND Connection of an electrical unit to the engine or frame to return the current to its source.

HC Chemical formula for a hydrocarbon, such as gasoline.

HEADLAND RING A compression ring having the cross-sectional shape of an L. Used as the top compression ring.

HEAT A form of energy released by the burning of fuel.

HEAT OF COMPRESSION Increase of temperature brought about by compression of air or air-fuel mixture.

HELI-COIL A thread insert used to repair worn or damaged threads. It is installed in a retapped hole to bring the screw thread down to original size.

HEMISPHERIC COMBUSTION CHAMBER A combustion chamber having a resemblance to a hemisphere, or round ball cut in half.

HIGH COMPRESSION A term used to refer to the increased compression ratios of modern engines as compared to the compression ratios of engines built in past years.

HONE An abrasive stone that is rotated in a bore or bushing to remove material.

HORSEPOWER (hp) A measure of mechanical power, or the rate at which work is done. One horsepower equals 33,000 foot-pounds of work per minute.

HYDRAULIC VALVE LIFTER A valve lifter that by means of oil pressure maintains zero valve clearance so that valve noise is reduced.

HYDROCARBON (HC) A compound made of the elements hydrogen and carbon. Gasoline is a blend of hydrocarbons refined from crude oil.

HYDROMETER A device used to measure specific gravity. A test instrument, consisting of a float inside a tube, which measures the specific gravity of a liquid; used to measure the specific gravity of battery electrolyte to determine the state of battery charge.

IDLE SPEED The speed, or rpm, at which the engine runs without load when the throttle is closed.

IGNITION In an engine, the act of the spark in starting the combustion process in the engine cylinder.

IGNITION COIL That part of the ignition system which acts as a transformer to step up the battery voltage to many thousands of volts; the high-voltage surge then produces a spark at the spark-plug gap.

IGNITION DISTRIBUTOR That part of the ignition system which closes and opens the circuit to the ignition coil with correct timing and distributes to the proper spark plugs the resulting high-voltage surges from the ignition coil.

IGNITION SWITCH The switch in the ignition system which is operated with a key to open and close the ignition primary circuit.

I-HEAD ENGINE An overhead-valve (OHV) engine with the valves in the cylinder head.

ihp See "Indicated horsepower."

INDICATED HORSEPOWER (ihp) The power produced within the engine cylinders before deducting any frictional loss.

INERTIA Property of objects that causes them to resist any change of speed or direction of travel.

IN-LINE ENGINE An engine in which all engine cylinders are in a single row, or line.

INTAKE MANIFOLD The part of the engine that provides a series of passages from the carburetor to the engine cylinders through which air-fuel mixture can flow.

INTAKE STROKE The piston stroke from TDC to BDC during which the intake valve is open and the cylinder receives a charge of air-fuel mixture.

INTAKE VALVE The valve that opens to permit air-fuel mixture to enter the cylinder on the intake stroke.

JOURNAL The part of a rotating shaft which turns in a bearing.

KEY A wedgelike metal piece, usually rectangular or semicircular, inserted in grooves to transmit torque while holding two parts in relative position; the small strip of metal with coded peaks and grooves used to operate a lock, such as an ignition.

KILOGRAM (kg) In the metric system, a unit of weight, or mass, approximately equal to 2.2 pounds.

KILOMETER (km) In the metric system, a unit of linear measure equal to 0.621 mile.

KILOWATT (kW) In the metric system, a measure of power. One horsepower equals 0.746 kilowatt.

KINETIC ENERGY The energy of motion: the energy stored in a moving body as developed in its momentum—for example, the kinetic energy stored in a rotating flywheel.

KNOCK The heavy metallic sound created in an engine, varying with engine speed and usually caused by a loose or worn bearing.

kW See "Kilowatt."

LAPPING A method of seating engine valves by which the valve is turned back and forth on the seat.

L-HEAD ENGINE A type of engine in which the valves are located in the cylinder block.

LIFTER See "Valve lifter."

LIQUID-COOLED ENGINE An engine that is cooled by the circulation of liquid coolant around the cylinders.

LITER (L) In the metric system, a measure of volume, approximately equal to 0.2642 U.S. gallon.

LOBE The projecting part, such as the rotor lobe, or the cam lobe.

LOCKNUT A second nut turned down on a holding nut to prevent loosening.

LUBRICATING SYSTEM The system in the engine that supplies moving engine parts with lubricating oil to prevent actual contact between any of the moving metal surfaces.

LUGGING Low-speed, full-throttle engine operation in which the engine is heavily loaded and overworked.

MAGNETO An engine-drive device that generates its own primary current, transforms that current into high-voltage surges, and delivers them to the proper spark plugs.

MAIN BEARINGS In the engine, the bearings that support the crankshaft.

MANIFOLD VACUUM The vacuum in the intake manifold that develops as a result of the vacuum in the cylinders on their intake strokes.

MECHANICAL EFFICIENCY In an engine, the ratio between brake horsepower and indicated horsepower.

MECHANISM A system of interrelated parts that make up a working assembly.

METER (m) A unit of linear measure in the metric system equal to 39.37 inches. Also, the name given to test instruments that measure a substance passed through it—for example, an ammeter. Also, any device that measures and controls the discharge of the substance passing through it. For example, a carburetor jet is used to meter fuel flow.

METERING ROD AND JET A device, consisting of a small movable rod, which has a varied diameter, and a jet that increases or decreases fuel flow according to engine throttle opening, engine load, or a combination of both.

MICROMETER A precision measuring device that measures small distances, such as crankshaft or cylinder bore diameter or thickness of an object. Also called a mike.

MIKE Slang term for micrometer.

MILLIMETER (mm) In the metric system, a unit of linear measure approximately equal to 0.039 inch.

MISSING In the engine, the failure of the air-fuel mixture in a cylinder to ignite when it should.

MOTOR A device for converting electrical energy into mechanical energy—for example, the starting motor.

MOTOR VEHICLE Any type of self-propelled vehicle mounted on wheels or tracks.

MUFFLER In the exhaust, a device through which the exhaust gases must pass and which muffles the sound.

MULTIPLE-VISCOSITY OIL An engine oil which has a low viscosity when cold (for easier cranking) and a higher

viscosity when hot (to provide adequate engine lubrication).

MUSHROOMED VALVE STEM The condition that exists on a worn valve stem when the tip, or butt end, has mushroomed and metal is hanging over the valve guide. Correction requires removal of the mushroomed metal.

NEEDLE BEARING Antifriction bearing of the roller type; the rollers are very small in diameter (needle-size).

NO_x Chemical formula for nitrogen oxides.

OCTANE RATING A measure of antiknock property of gasoline. The higher the octane rating, the more resistant the gasoline is to knocking, or detonation.

OHC Overhead camshaft.

OIL A liquid lubricant derived from crude oil used to provide lubrication between moving parts. In a diesel engine, oil is used for fuel.

OIL-CONTROL RINGS The lower ring or rings on a piston designed to prevent excessive amounts of oil from working up into the combustion chamber.

OIL COOLER A small radiator through which the oil flows to lower its temperature.

OIL DILUTION Dilution of oil in the crankcase caused by leakage of liquid gasoline from the combustion chamber past the piston rings.

OIL FILTER The filter through which the crankcase oil passes to remove any impurities from the oil.

OIL-LEVEL INDICATOR The indicator, usually called the dipstick, that is removed to determine the level of oil in the crankcase.

OIL PAN The detachable lower part of the engine, made of sheet metal, which encloses the crankcase and acts as an oil reservoir.

OIL PUMP In the lubricating system, the device that delivers oil from the oil pan to the various moving engine parts.

OIL PUMPING Passing of oil past the piston rings into the combustion chamber because of defective rings, worn cylinder walls, etc.

OIL SEAL A seal placed around a rotating shaft, or other moving part, to prevent passage of oil.

OIL STRAINER A wire mesh screen placed at the inlet end of the oil-pump pickup tube to prevent dirt and other large particles from entering the oil pump.

ORIFICE A small opening, or hole, into a cavity.

OVERHEAD CAMSHAFT (OHC) ENGINE An engine in which the camshaft is located in the cylinder head, or heads, instead of in the cylinder block.

OVERHEAD VALVE (OHV) ENGINE An engine in which the valves are mounted in the cylinder head above the combustion chamber; the camshaft is usually mounted in the cylinder block, and the valves are actuated by push rods.

OVERSQUARE A term applied to engines which have a bore larger than the length of stroke.

PANCAKE ENGINE An engine with two rows of cylinders which are opposed and on the same plane, usually set horizontally.

PCV Positive crankcase ventilation.

PILOT BEARING A small bearing, in the center of the flywheel end of the crankshaft, which carries the forward end of the clutch shaft.

PING The sound resulting from sudden ignition of the air-fuel charge in the engine combustion chamber; characteristic sound of detonation.

PISTON A movable part, fitted to a cylinder, which can receive or transmit motion as a result of pressure changes (fluid, vapor, or gas) in the cylinder.

PISTON DISPLACEMENT The cylinder volume displaced by the piston as it moves from the bottom to the top of the cylinder during one complete stroke.

PISTON PIN Also called wrist pin. The cylindrical or tubular metal piece that attaches the piston to the connecting rod.

PISTON-RING COMPRESSOR A special tool used in engine overhaul work to compress the piston rings inside the piston grooves so the piston-and-rings assembly may be installed in the engine cylinder.

PISTON RINGS Rings fitted into grooves in the piston. There are two types: compression rings for sealing the compression into the combustion chamber and oil rings to scrape excessive oil off the cylinder wall. This prevents the oil from working up into and burning in the combustion chamber.

PISTON SKIRT The lower part of the piston below the piston-pin hole.

PISTON SLAP Hollow, muffled, bell-like sound made by an excessively loose piston slapping the cylinder wall.

PLASTIC GASKET COMPOUND A plastic paste in a tube which can be laid in any shape to make a gasket.

PLASTIGAGE A plastic material that comes in various sizes of wirelike lengths and is used to measure crankshaft main-bearing and connecting-rod bearing clearances.

POLLUTANT Any gas or substance in the exhaust gas from the engine or evaporating from the fuel tank or carburetor that adds to the pollution of the atmosphere.

POPPETT VALVE A mushroom-shaped valve, widely used in automotive engines.

PORT In an engine, the valve port or opening in which the valve operates and through which air-fuel mixture or burned gases pass.

POSITIVE CRANKCASE VENTILATING (PCV) SYSTEM A crankcase ventilating system in which the blow-by gas in the crankcase is returned to the intake system of the engine to be burned. This prevents the blow-by gas from escaping into the atmosphere.

POWER The rate at which work is done. A common power-measuring unit is the horsepower, which is equal to 33,000 foot-pounds per minute.

POWER PLANT The engine, or power-producing mechanism.

POWER STROKE The piston stroke from TDC to BDC during which the air-fuel mixture burns and forces the piston down so that the engine produces power.

POWER TRAIN The group of mechanisms that carry the rotary motion developed in the engine to the drive wheels. It includes the clutch, transmission, drive shaft, differential, and axles.

PRECISION-INSERT BEARINGS Bearings of the type that can be installed in an engine without reaming, honing, or grinding.

PREIGNITION Ignition of the air-fuel mixture in the engine cylinder (by any means) before the ignition spark occurs at the spark plug.

PRELOAD In bearings, the amount of load originally imposed on a bearing before actual operating loads are imposed. This is done by bearing adjustments before operation and ensures alignment and minimum looseness in the system.

PRESS FIT A fit so tight that the pin has to be pressed into place, usually with an arbor or hydraulic press.

PRESSURE CAP A radiator cap with valves which causes the cooling system to operate under pressure and thus at a somewhat higher and more efficient temperature.

PRESSURE-FEED OIL SYSTEM A type of engine lubricating system that makes use of an oil pump to force oil through tubes and passages to the various engine parts requiring lubrication.

PRESSURE REGULATOR A regulating device which operates to prevent excessive pressure from developing. In the hydraulic systems, a valve that opens to release oil from a line when the oil pressure attains specified maximum.

PRESSURE-RELIEF VALVE A valve in the oil line that opens to relieve excessive pressures that the oil pump might develop.

psi Abbreviation for pounds per square inch; often used to indicate pressure of a liquid or gas.

PULLER Generally, a shop tool that permits removal of one closely fitted part from another without damage. Often contains a screw or screws which can be turned to apply gradual pressure.

PULLEY A metal wheel with a V-shaped groove around the rims, which drives or is driven by a belt.

PUSH ROD In the I-head engine, the rod between the valve lifter and the rocker arm.

QUENCH The space in some combustion chambers which absorbs enough heat to quench, or extinguish, the combustion flame front as it approaches a relatively cold cylinder wall. This prevents detonation of the end gas but results in hydrocarbon emissions.

RADIATOR In the cooling system, the device that removes heat from the coolant passing through it; it takes hot coolant from the engine and returns the coolant to the engine at a lower temperature.

RC ENGINE A rotary combustion, or Wankel, engine.

REAMER A metal-cutting tool with a series of sharp cutting edges that remove material from a hole when the reamer is turned in it.

REBORE To bore out a cylinder larger than its original size.

RECIPROCATING MOTION Motion of an object between two limiting positions: back and forth, or up and down, etc.

REED VALVE A type of valve used in the crankcase of some two-cycle engines. Air-fuel mixture enters the crankcase through the reed valve, which then closes as pressure builds up in the crankcase.

REGULATOR In the charging system, a device that controls alternator output to prevent excessive voltage.

RING EXPANDER A special tool used to expand piston rings for installation on the piston.

RING GAP The gap between the ends of the piston ring with the ring in place in the cylinder.

RING GROOVES Grooves cut in a piston into which the piston rings are assembled.

RING RIDGE Ridge left at the top of the cylinder as the cylinder wall below it is worn by piston-ring movement.

RING-RIDGE REMOVER A special tool used for removing the ring ridge from the cylinder.

ROCKER ARM In an I-head engine, a device that rocks on a shaft or pivots on a stud as the cam moves the push rod, causing the valve to open.

ROD BEARINGS In the engine, the bearings in the connecting rod in which a crankpin of the crankshaft rotates; also called connecting-rod bearings.

ROD BIG END The end of the connecting rod that attaches around the crankpin.

ROD BOLTS Special bolts used on the connecting rod to attach the cap.

ROD SMALL END The end of the connecting rod through which a piston pin passes to connect the piston to the connecting rod.

ROTARY Action of a part that continually rotates, or turns around.

ROTARY COMBUSTION (RC) ENGINE See "Wankel engine."

ROTOR A revolving part of a machine, such as alternator rotors, distributor rotors, and Wankel-engine rotors.

ROTOR OIL PUMP A type of oil pump using a pair of rotors, one inside the other, to produce the oil pressure required to circulate oil to engine parts.

rpm Revolutions per minute.

SA Designation of lubricating oil that is acceptable for use in engines operated under the mildest conditions.

SB Designation of lubricating oil that is acceptable for minimum-duty engines operated under mild conditions.

SC Designation of lubricating oil that meets requirements for use in gasoline engines in 1964–1967 model passenger cars and trucks.

SCORED Scratched or grooved: a cylinder wall may be *scored* by abrasive particles moved up and down by the piston rings.

SCRAPER A device in engine service to scrape carbon, etc., from engine block, pistons, etc.

SCRAPER RING On a piston, a type of oil-control ring designed to scrape excess oil back down the cylinder into the crankcase.

SCREEN A fine-mesh screen in the fuel and lubricating system that prevents large particles from entering the system.

SCUFFING A type of wear of moving parts characterized by transfer of material from one to the other part and pits or grooves in the mating surfaces.

SD Designation of lubricating oil that meets requirements for use in gasoline engines in 1968–1970 model passenger cars and some trucks.

SE Designation of lubricating oil that meets requirements for use in gasoline engines in 1973 and later cars and certain 1971 model passenger cars and trucks.

SEAL A material, shaped around a shaft, used to close off the operating compartment of the shaft, preventing oil leakage.

SEALER A thick, tacky compound, usually spread with a brush, which may be used as a gasket, or sealant, to seal small openings or surface irregularities.

SEAT The surface upon which another part rests, such as a valve seat. Also term applied to the process by which a part wears into fit; for example, "Piston rings *seat* after a few miles of driving."

SEMICONDUCTOR A material that acts as an insulator under some conditions and as a conductor under other conditions.

SERVICE MANUAL Also called shop manual; the book published by each engine manufacturer listing specifications and service procedures for each make and model of engine built.

SERVICE RATINGS For lubricating oil used in engines, a designation that indicates the type of service for which the oil is best suited. See also "SA," "SB," "SC," "SD," and "SE."

SHIM A slotted strip of metal used as a spacer.

SHRINK FIT A tight fit of one part in another achieved by heating or cooling one part and then assembling it with the other part. If heated, the part then shrinks on cooling to provide a shrink fit. If cooled, the part expands on warming to provide the fit.

SIDE CLEARANCE The clearance between the sides of moving parts that do not serve as a load-carrying surface.

SINGLE-CHAMBER CAPACITY In a Wankel engine, a method of comparing displacement, or size, between engines.

SLIP JOINT In the power train, a variable-length connection that permits the drive shaft to change effective length.

SLUDGE Accumulation in oil pan, containing water, dirt, and oil; sludge is very viscous and tends to prevent lubrication.

SMOG A term coined from smoke and fog which is applied to the foglike layer that hangs over many areas under certain atmospheric conditions. Smog is compounded from smoke, moisture, and numerous chemicals which are produced by combustion (from power plants, automotive engines, incinerators, etc.) and from numerous natural and industrial processes. The term is used generally to describe any condition of dirty air and/or fumes or smoke.

SOHC ENGINE Engine with a single overhead camshaft.

SOLDERING The uniting of pieces of metal with solder, flux, and heat.

SOLVENT TANK In the shop, a tank of cleaning fluid in which most parts are brushed and washed clean.

SPARK PLUG The assembly, which includes a pair of electrodes and an insulator, that has the purpose of providing a spark gap in the engine cylinder.

SPARK-PLUG HEAT RANGE The distance heat must travel from the center electrode to reach the outer shell of the plug and enter the cylinder head.

SPECIFIC GRAVITY A measure of the weight per unit volume of a liquid as compared with the weight of an equal volume of water.

SPLASH-FEED OIL SYSTEM A type of engine lubricating system that depends on splashing of the oil for lubrication to moving engine parts.

SPLINE Slot or groove cut in a shaft or bore; a splined shaft onto which a hub, wheel, gear, etc., with matching splines in its bore is assembled so that the two must turn together.

SPRING An elastic device which yields under stress or pressure but returns to its original state or position when the stress or pressure is removed.

SPRING RETAINER In the valve train, the piece of metal that holds the spring in place and is itself locked in place by the valve-spring-retainer locks.

SQUARE ENGINE An engine having the bore and stroke of equal measurements.

SQUISH The action in some combustion chambers in which the last part of the compressed mixture is pushed, or squirted, out of a decreasing space between the piston and cylinder head.

STARTING MOTOR An electric motor in the electric system that cranks the engine, or turns the crankshaft, for starting.

STATIC FRICTION Friction between two bodies at rest.

STEPPED FEELER GAUGE A feeler gauge which has a thin tip and is thicker along the rest of the gauge; a "go, no-go" gauge.

STORAGE BATTERY A lead-acid electrochemical device that changes chemical energy into electrical energy; that part of the electric system which acts as a reservoir for electric energy, storing it in chemical form.

STROKE In an engine, the distance that the piston moves from BDC to TDC.

SUPERCHARGER A device in the intake system of the engine which pressurizes the ingoing air-fuel mixture. This increases the amount of mixture delivered to the cylinders and thus increases engine output. If the supercharger is driven by the engine exhaust gas, it is called a turbocharger.

SURFACE IGNITION Ignition of the air-fuel mixture in the combustion chamber produced by hot metal surfaces or heated particles of carbon.

TAPER A shaft or hole that gets gradually smaller toward one end. In an engine cylinder, the uneven wear which is more at the top than at the bottom.

TAPPET See "Valve lifter."

TDC Top dead center.

TEL Tetraethyl lead.

TETRAETHYL LEAD A chemical put into engine fuel which increases octane rating, or reduces spark-knock tendency. Also called ethyl and tel.

THERMAL EFFICIENCY Relationship between the power output and the energy in the fuel burned to produce the output.

THERMOSTAT A device that operates on, or regulates, temperature changes. Several thermostats are used in engines.

THROTTLE VALVE The round disk valve in the throttle body of the carburetor that can be turned to admit more or less air, thereby controlling engine speed.

THROW-A-ROD Expression used to designate an engine with a loose, knocking connecting-rod bearing or an engine that has broken a connecting rod and shoved it through the cylinder block or pan.

THRUST BEARING Specifically in the engine, the main bearing that has thrust faces which prevent excessive endwise movement of the crankshaft.

THYRISTOR A type of semiconductor device that acts as a switch. It turns on when a certain voltage is applied to the gate, and it turns off when the current flowing between the other two terminals stops or reverses.

TIMING In the engine, refers to timing of valves, timing of ignition, and their relation to the piston position in the cylinder.

TIMING CHAIN A chain driven by a sprocket on the crankshaft that drives the sprocket on the camshaft.

TIMING GEARS A gear on the crankshaft that drives the camshaft by meshing with a gear on its end.

TIMING LIGHT A light that is connected to the ignition system to flash each time the No. 1 spark plug fires; used for adjusting the timing of the ignition spark.

TOP DEAD CENTER (TDC) The piston position when the piston has moved to the top of the cylinder and the center line of the connecting rod is parallel to the cylinder walls.

TORQUE Turning or twisting effort, usually measured in pound-feet (kilogram-meters).

TORQUE WRENCH A special wrench that indicates the amount of torque being applied to a nut or bolt.

TORSIONAL BALANCER See "Vibration damper."

TORSIONAL VIBRATION Vibration in a rotary direction that causes a twist-untwist action on a rotating shaft; the actions in a rotating shaft that repeatedly moves ahead or lags behind the remainder of the shaft—for example, the actions as a crankshaft responds to the cylinder firing impulses.

TRANSISTOR An electronic device that can be used as an electric switch; used in electronic ignition systems to replace the contact points.

TRANSMISSION The device in the power train that provides different gear ratios between the engine and rear wheels, as well as reverse.

TROUBLE DIAGNOSIS The detective work necessary to run down the cause of a trouble. Also implies the correction of the trouble by elimination of cause.

TUNEUP The procedure of inspection, testing, and adjusting an engine and replacing any worn parts to restore the engine to its best performance.

TURBOCHARGER A supercharger driven by the engine exhaust gas.

TURBULENCE The state of being violently disturbed. In the engine, the rapid swirling motion imparted to the air-fuel mixture entering the cylinder.

TWIST DRILL Drill.

TWO-CYCLE Short for "two-stroke-cycle."

TWO-STROKE CYCLE The series of events taking place in a two-stroke-cycle engine, which are intake, compression, power, and exhaust, all of which take place in two piston strokes. A two-stroke-cycle engine is also called two-cycle engine, or a two-stroker.

VACUUM An absence of air or other substance.

VACUUM ADVANCE Ignition-spark advance resulting from partial vacuum in intake manifold.

VACUUM GAUGE In engine service, a device that measures intake-manifold vacuum and thereby indicates actions of engine components.

VALVE A device that can be opened or closed to allow or stop the flow of a liquid, gas, or vapor from one place to another.

VALVE CLEARANCE The clearance between the rocker arm and the valve-stem tip in an overhead-valve engine; the clearance in the valve train when the valve is closed.

VALVE FLOAT The condition that exists when the engine valves do not follow the cam; failure of the valves to close at the proper time.

VALVE GRINDING Refacing a valve in a valve-refacing machine.

VALVE GUIDE The cylindrical part in the cylinder block or head in which the valve is assembled and in which it moves up and down.

VALVE-IN-HEAD ENGINE An I-head engine.

VALVE LASH See "Valve clearance."

VALVE LIFTER Also called lifter, tappet, valve tappet, and cam follower. A cylindrical part of the engine which rests on a cam of the camshaft and is lifted, by cam action, so that the valve is opened.

VALVE-LIFTER FOOT The bottom end of the valve lifter; the part that rides on the cam lobe.

VALVE OVERLAP Number of degrees of crankshaft rotation through which both the intake and exhaust valves are open together.

VALVE RACK Any wood or metal container or holder which identifies and keeps the valves in order.

VALVE-REFACING MACHINE A machine for removing material from the seating face of valves so that a new face appears.

VALVE ROTATOR Device used in place of the valve-spring retainer; it has a built-in mechanism to rotate the valve slightly each time it opens.

VALVE SEAT The surface in the cylinder head against which the valve face comes to rest.

VALVE-SEAT INSERTS Metal rings inserted in valve seats, usually exhaust-valve seats; they are of special metal able to withstand high temperatures.

VALVE-SEAT RECESSION Also known as lash loss; the tendency for valves, in some engines run on unleaded gasoline, to contact the seat in such a way that the seat wears away, or recesses into the cylinder head.

VALVE-SPRING RETAINER The device on the valve stem that holds the spring in place.

VALVE-SPRING-RETAINER LOCK The locking device on the valve stem that locks the spring retainer in place.

VALVE STEM The long, thin section of the valve that fits into the valve guide.

VALVE-STEM SEAL A device placed on or surrounding the valve stem to reduce the amount of oil which can get on the stem and thereby work its way down into the combustion chamber.

VALVE TAPPET Valve lifter.

VALVE TIMING The timing of valve opening and closing in relation to piston position in the cylinder.

VALVE TRAIN The valve-operating mechanism of an engine, from the camshaft to the valve.

VAPOR LOCK A condition in the fuel system in which gasoline has vaporized and turned to bubbles in the fuel line or fuel pump so that fuel delivery to the carburetor is prevented or retarded.

VENTURI In the carburetor, the restriction in the air horn that produces the vacuum responsible for the movement of gasoline into the passing air.

VI See "Viscosity index."

VIBRATION A complete rapid motion back and forth; oscillation.

VIBRATION DAMPER A device attached to the crankshaft of an engine which opposes crankshaft torsional vibration, that is, the twist-untwist actions of the crankshaft caused by the cylinder firing impulses. Also called harmonic balancer.

VISCOSITY The resistance to flow that a liquid has. A thick oil has greater viscosity than a thin oil.

VISCOSITY INDEX A measurement used to determine how much an oil viscosity changes with heat.

VISCOSITY RATINGS Oil viscosity is rated two ways: for winter use and for summer use. The winter grades are SAE 5W, SAE 10W, and SAE 20W. For summer driving, the grades are SAE 20, SAE 30, SAE 40, and SAE 50. Many oils have multiple-viscosity ratings, for example, SAE 10W-30.

VISCOUS Thick, tending to resist flowing.

VISCOUS FRICTION Friction between layers of a liquid.

VOLATILITY A measurement of the ease with which a liquid vaporizes.

VOLUMETRIC EFFICIENCY Ratio between the amount of air-fuel mixture that actually enters an engine cylinder and the theoretical amount that could enter under ideal conditions.

V-TYPE ENGINE Engine with two banks of cylinders set at an angle to each other to form a V.

WANKEL ENGINE A rotary-type engine in which a three-lobe rotor turns eccentrically in an oval chamber.

WATER JACKET The space between inner and outer shells of the cylinder block or head through which coolant can circulate.

WATER PUMP In the cooling system, the device that maintains circulation of the coolant between the engine water jackets and the radiator.

WEDGE COMBUSTION CHAMBER A combustion chamber resembling, in shape, a wedge.

WORK The changing of the position of a body against all opposing force, measured in foot-pounds (meter-kilograms). Product of force times the distance through which it acts.

WRIST PIN Piston pin.

ZENER DIODE A special type of diode that will conduct current in its normally blocked (or reverse) direction under certain conditions.

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